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NAVAL POSTGRADUATE SCHOOL
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THESIS

SENSITIVITY STUDY OF THE XR-3 LOADS AND MOTIONS COMPUTER PROGRAM SIDEWALL PARAMETERS AND FORCES ON ROLL BEHAVIOR IN CALM SEA AND A COMPARISON TO TESTCRAFT TURN MANEUVER DATA

by

Rolf-Guenther Riedel

June 1977

Thesis Advisor: Alex Gerba, Jr.

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I. INTRODUCTION

A. Background

In the past several years the Surface Effect Ship (SES) has received increased attention in the United States Navy and detailed investigations of its sea performance have been carried out. The two major categories of SES are the Air Cushion Vehicle (ACV) and the Captured Air Bubble Ship (CAB). The CAB-type of craft has become of primary interest to the United States Navy and two of the constructed testcraft are the Bell Aerospace Systems 100-B and the XR-3 of approximately 100 and 3 tons of displacement, respectively. In 1976 the U.S. Navy Surface Effect Ship SES 100-B of the CAB-type established a world speed record for surface type ships of 89.4 knots. In April 1976 the SES 100-B launched a missile at 60 knots. The launch was successful and the missile hit its target five miles away.

In order to investigate the characteristics of the CAB-type SES under any design and operating conditions without the costly need of modifying the actual craft, a Loads and Motions digital computer program was developed by Oceanics, Inc. [Ref. 1]. In 1970 the XR-3 testcraft was delivered to the Naval Postgraduate School and Leo and Boncal converted the 100-B Loads and Motions program to represent the XR-3. Since there were substantial design differences between these two ships programming modifications were required in certain subroutines.

B. Objectives

The purpose of this thesis is to investigate one aspect of safe maneuverability of these high speed ships, i.e. their roll behavior in a turn maneuver. To fulfill this objective the sensitivity of the simulated XR-3 roll behavior in turn maneuvers as it is represented by the Loads and Motions Program is investigated for its dependence on changes in sidewall characteristics. The effect of modifications in the added mass computation, sidewall parameters and force calculations as well as propulsion and rudder input parameters are investigated. An evaluation of the computed performance is obtained by comparison with experimentally measured steady state roll conditions.

II. INITIAL REMARKS

A. PROBLEM OF REPEATABILITY

It has been this author's experience as well as all previous investigators at the Naval Postgraduate School using the XR-3 Loads and Motions Program that there have been no observed problems related to repeating the results for a given input condition. However, during the author's first studies of the Loads and Motions Program as listed in Menzel's thesis [Ref. 2] an attempt was made to duplicate some of the simulation runs given in that reference work. It was found necessary as a first step to restore the simulation program on the IBM 360/67 computer from a card source onto a disk.[1] Using the input conditions stated in Ref. 2 it was impossible to obtain identical time histories, e.g. for turns. Each time subroutine SIDEWALL was read into the computer together with the data input deck, thereby overriding the stored program, an error message in the printed output indicated that a division by zero occurred in this subroutine. The error message was not generated when the stored program which contained an identical version of subroutine SIDEWALL was called. A closer look revealed that in the SIDEWALL-version given in Ref. 2 the variable PBAR (plenum pressure) was neither

---

[1] It should also be noted that results obtained in Ref. 2 used the IBM 360/67 Release 20.6 system while the results obtained in this work used the 21.8B Release with HASP installed.

defined nor transferred by a COMMON-statement and therefore a default value of zero was used during the computation of PBHEAD (see Appendix C, SDWL 0440). The missing statement

PBAR = PB - PINF

was inserted to subroutine SIDEWALL. With this correction the new results were slightly closer to those given in Ref. 2.

The table given below compares output values for roll and pitch angle in a turn at 20 kn with constant thrust and a 35 degrees rudder step input under calm sea conditions.

TABLE I

20 kn turn at 35 deg rudder angle

	without PBAR-card	with PBAR-card	Ref. 2	relative deviation
Roll angle (deg)				
first peak	7.44	7.39	7.2	2.6 %
avrg at 20 sec	2.65	2.77	3.1	11.9 %
Pitch angle (deg)				
first peak	1.34	1.33	1.2	9.8 %
avrg at 20 sec	0.99	0.94	0.8	14.9 %

Although the differences between columns 2 and 3 in TABLE I might be considered to be small as far as magnitudes are concerned , the relative deviation is up to 15 % as shown in column 4. But what is more important is the fact that the roll and pitch angle responses for the uncorrected (plots 1 and 2 in Appendix A) as well as for the corrected program (plots 3 and 4) show an unstable craft behavior for t>40 sec where the pitch angle increases rapidly while the roll angle

decreases rapidly approaching the zero degree value. This unstable condition is probably due to the 35 degrees rudder step input at 20 kn, as it is used in Menzel's study, which is physically unreal since it could never be introduced to the XR-3 testcraft in an actual run at that speed. Therefore rudder angles of up to 15 degrees introduced at a rate of 5 deg/sec will be used throughout this work, as it is also done on the testcraft.

Also, regarding plots 1-4 again and not considering whether they really reflect the actual craft behavior, it should be noted that a short time history (t<20 sec in Ref. 2) could possibly result in wrong conclusions because the unstable condition is not evident at that instant of time. Therefore, time histories of up to 40 or 50 seconds will be shown throughout this study.

B. STEADY STATE CONDITIONS

Due to the change in subroutine SIDEWALL as mentioned in the preceding section the steady state conditions for straight runs in calm water have been reestablished for various speeds and are listed in Table II.

Table II

Steady State Conditions

Speed (kn)	Draft (in)	Pitch angle (deg)	Plenum pressure (psf)	Thrust (lb)
10.0	8.17	1.62	23.93	400.61
12.5	7.03	1.11	24.84	349.42
15.0	6.74	0.84	24.84	335.71
17.5	6.41	0.63	24.84	346.45
20.0	6.12	0.48	24.84	373.44
22.5	5.87	0.36	24.84	411.53
25.0	5.66	0.29	24.84	458.62
27.5	5.48	0.25	24.84	513.31
30.0	5.34	0.26	24.84	574.43

These steady state conditions have been established by first executing the XR-3 Loads and Motions Program with constant speed for 40 seconds and then repeating the run keeping the evaluated thrust constant. A comparison of these steady state values with those given in Ref. 2 shows differences especially in the lower and upper speed range of again up to 15 % the cause of which could not be suspected anywhere else since the simulation program has not been changed since last used by Menzel.

C. SIGN CONVENTIONS

The sign conventions used in the XR-3 Loads and Motions Program are identical to those used in Report 71-84 by Oceanics Incorporated [Ref. 1]. A right handed coordinate system is applied to the craft with the positive X-axis being measured forward and the lateral Y-axis being measured positive to starboard. The vertical Z-axis is measured positive downward. Identical signs are used for respective forces along those axes.

The signs of the angles are defined in the following manner :

pitch angle being positive upward
(boat noses up)

roll angle being positive to starboard
(boat rolls to starboard)

yaw angle being positive to starboard
(boat turns to starboard)

rudder angle being positive to port
(right rudder, boat turns to port) .

Zero pitch and roll angle are referenced to the X-Y plane parallel to the water surface.

III. INVESTIGATION OF SIDEWALL EFFECTS

A. ADDED MASS EFFECT

1. Theory

A basic element in representing the hydrodynamic forces by use of slender body theory are the two-dimensional sectional values of lateral added mass A22 of the sidewalls, which are necessary for the determination of the lateral forces, as well as the two-dimensional sectional vertical added mass A33 which is also used in determining the roll moment. These two-dimensional added mass values are given in the 'Surface Effect Ships Aero/Hydrodynamics Technology Design Manual' [Ref. 3] as

$$A22 = C_h * RHO * PI * D * D / 2.0$$

and

$$A33 = C_v * RHO * B * B / 8.0$$

where C_h is the lateral added mass coefficient

C_v is the vertical added mass coefficient

RHO is the specific density of sea water

D is the local draft

and B is the width at the local sidewall waterline.

The C_h and C_v values originally selected in Ref. 1 were those corresponding to high speed with C_h=0.4 and C_v=1.0. But in order to account for variations in sidewall shape, and their influence on the effective lateral added mass, the results of the research work described in Ref. 3 led to an average value of C_h=0.8. This new coefficient improved the agreement between theoretical and experimental data as stated in Ref. 3 . In the present XR-3 Loads and Motions Program a value of C_h=0.4 is used in accordance with Ref. 1 and the effect of letting C_h=0.8 will be investigated in later parts of this thesis.

Considering the equation for the vertical added mass A33, a major difference has been found between that one given in Ref. 3 and the one used in the XR-3 Loads and Motions Program (e.g. Ref. 2), where in accordance with Ref. 1 (1971) there was an additional PI-factor in the A33s equation. The letter 's' indicates that the computation of the added mass is done at the craft's stern. Since Ref. 3 (1976) reflects the experimental and theoretical work being done based on Ref. 1, the A33s equations in subroutines SIDEWALL and SIDETAB have now been changed to the new form given above.

2. New Steady State Conditions

The change in the simulated XR-3 performance due to the reformulated A33s computation can be observed from TABLE III giving the new steady state conditions for straight runs in calm sea for various speeds which are identical for both (0.4 and 0.8) lateral added mass coefficients.

TABLE III
Steady state conditions
(new A33s)

Speed (kn)	Draft (in)	Pitch angle (deg)	Plenum pressure (psf)	Thrust (lb)
15.0	6.80	0.86	24.84	336.30
17.5	6.46	0.65	24.84	347.23
20.0	6.17	0.49	24.84	374.38
22.5	5.92	0.37	24.84	412.62
25.0	5.71	0.30	24.84	459.90
27.5	5.53	0.27	24.84	514.89
30.0	5.40	0.28	24.84	576.66

Comparing these steady state values with those previously given in TABLE II in Sect. II.B one finds in general for all speeds that

- draft has increased by about 0.05 in (0.8 %)
- pitch angle has increased by 0.02 deg (2 to 7 %)
- thrust has slightly increased by less than 0.5 % .

3. Effect in a Turn maneuver

The effect of the change in the formulation of the vertical added mass in a simulated turn maneuver has been studied next. After a 5 sec straight run at 20 kn in calm sea a port rudder deflection was introduced at a rate of 5 deg/sec and then kept fixed at 15 degrees resulting in a turn to port. The deadrise forces are computed at the transom. In TABLE IV are shown the steady state conditions and the roll moments contributed from the bow seal (FKBS), stern seal (FKSS), sidewalls (FKSW), rudder (FKRUD), propulsion system (FKP), aerodynamics (FKAED) and plenum pressure (ABPB*PHI*Z).

TABLE IV

Steady state conditions in 20 kn turn

15 deg port rudder angle

		old A33s	new A33s	deviation
pitch angle	(deg)	0.48	0.52	8.3 %
roll angle	(deg)	2.0	1.98	- 1.0 %
draft	(in)	5.86	5.94	1.4 %
speed	(kn)	19.25	19.27	0.1 %
moments:				
	FKBS	-391.1	-386.3	- 1.2 %
	FKSS	- 3.6	- 3.6	0.0 %
	FKSW	191.0	202.0	5.8 %
	FKRud	- 97.5	-110.0	-12.8 %
	FKP	0.2	0.2	0.0 %
	FKAed	- 54.4	- 53.5	1.7 %
	ABPB*PHI*Z	355.4	351.9	1.0 %

From TABLE IV it can be seen that, due to the modified A33s computation, the counteracting roll moments from the sidewall (FKSW) and rudder (FKRUD) changed by about 6 and 13 %, respectively, resulting in only a little effect in generating a tendency toward a smaller roll angle which is directed out of the turn. Other major contributions to the roll angle are from the bow seal (FKBS directed into the turn) and from the plenum pressure (ABPB*PHI*Z) directed out of the turn. The corresponding plots (plots 5 - 8 for old A33s, plots 9 - 12 for new A33s) show that with the new equation for A33s the pitch and roll angle response curves are less damped than they were using the former equation for vertical added mass calculation as would be expected.

It should be noted that the roll moment due to rudder is fairly large and changes quite significantly while the moment contributed by the propulsion is very small and constant. The cause of this will be investigated in chapter IV.

B. DEADRISE ANGLE

1. Background

Surface Effect Ships (SES) of the captured air bubble type (CAB) have rigid sidewalls immersed into the water, thereby - together with the bow and stern seal - capturing the air in the plenum chamber and reducing air leakage. Since the sidewalls of the XR-3 are not uniform in cross-sectional shape throughout their length but are curved on the outboard side near the bow similar to a single hull ship, the expression "sidehulls" would be more appropriate, as can be found in modern literature.

The importance of the correct understanding of the effect of the sidewalls on the craft's performance is readily seen from a report on SES Research with the XR-1 testcraft [Ref. 5]. As reported, the first test series were carried out successfully with a 45 degrees sidewall deadrise angle, which is the angle between the horizontal plane and the ship's outer sidewall surface. In 1964, after a modification of the craft to 60 degrees deadrise angle and articulating seals, an unstable roll condition occurred during a turn at 35-37 knots, a maneuver performed many times before. The testcraft heeled out of the turn , nosed down due to the retraction of the bow seal, continued its outward roll motion and then flipped over. The report, however, does not mention the rudder action generating the turn. After this accident, the deadrise angle had been changed back to 45 degrees. From this experience the surface effect ship's roll stability should be expected to

be sensitive to the deadrise angle and an investigation of this sensitivity is reported in the following sections.

2. <u>Forces due to Deadrise Angle</u>

The deadrise angle, as pointed out by Ref. 3 and 4, has a major effect on the craft's roll motion and therefore is an important design consideration. During a turn the craft is desired to heel inboard, thereby minimizing the apparent transverse acceleration (a coordinated turn). For typical SES designs, it is not possible to achieve perfect coordination, but it is possible to achieve nearly flat turns if the craft is designed properly. The principal factors affecting roll stability at speed are

* sidewall geometry

* seal characteristics

* vertical location of the center of gravity.

The forces acting at the center of gravity station of the starboard sidewall in a port turn are shown in Figure 1. The centrifugal force generated acts away from the center of the turn. This force must be counteracted by hydrodynamic forces which are created by yawing the ship into the turn. To an observer aboard the craft, it would appear as if the craft is sideslipping. Wave buildup on the outboard sides of the sidewalls increases the pressure there, while only small pressure changes occur on the inboard side of the opposite sidewall generating a small (negligible) vertical force. The principal force arises from the outboard side of the sidewall. The direction of this force depends on the slope of the deadrise angle. If the resultant force passes above the center of gravity (solid line in Fig. 1) a restoring

moment results, tending to heel the craft into the turn thereby improving its roll stability. If the deadrise angle is chosen to be larger (e.g. 70 deg, shown dashed), the resultant force passes below the center of gravity, resulting in a moment tending to heel the craft out of the turn.

Thus, once the SES geometry and the exact vertical location of the center of gravity are known, an approximate check for stability in a turn can be made.

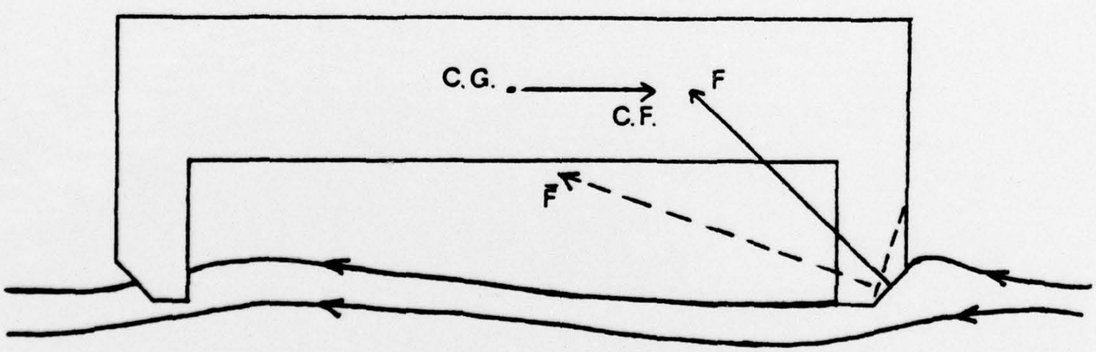


Figure 1 - GENERAL ROLL STABILITY CHECK IN A PORT TURN (C.F. CENTRIFUGAL FORCE, C.G. CENTER OF GRAVITY)

3. XR-3 Sidewall Geometry

From the construction data entered into the sidewall table (subroutine SIDETAB) Figure 2 has been drawn showing the cross sections at several selected stations of the starboard sidewall. Since in most simulation runs (which will be discussed later) draft was less than 7 inches, the deadrise angles for all stations immersing into the water have been calculated by straight line approximation and are given in TABLE V. The stations are counted from bow (station 0) to stern (station 28) and are not equally spaced for station numbers less than 11. The center of gravity has been located experimentally at station 14. The average deadrise angle of all stations listed is 64.3 degrees.

TABLE V

Deadrise angles (deg) for all stations

Straight line approximation for 7'' draft

Station	Deadrise angle	Station	Deadrise angle
5	67.6	17	62.1
6	70.8	18	64.0
7	57.9	19	65.3
8	54.4	20	66.7
9	53.7	21	68.1
10	53.7	22	6.96
11	53.7	23	70.3
12	55.6	24	71.1
13	57.3	25	72.4
14	58.5	26	73.8
15	59.7	27	76.9
16	60.9	28	78.8

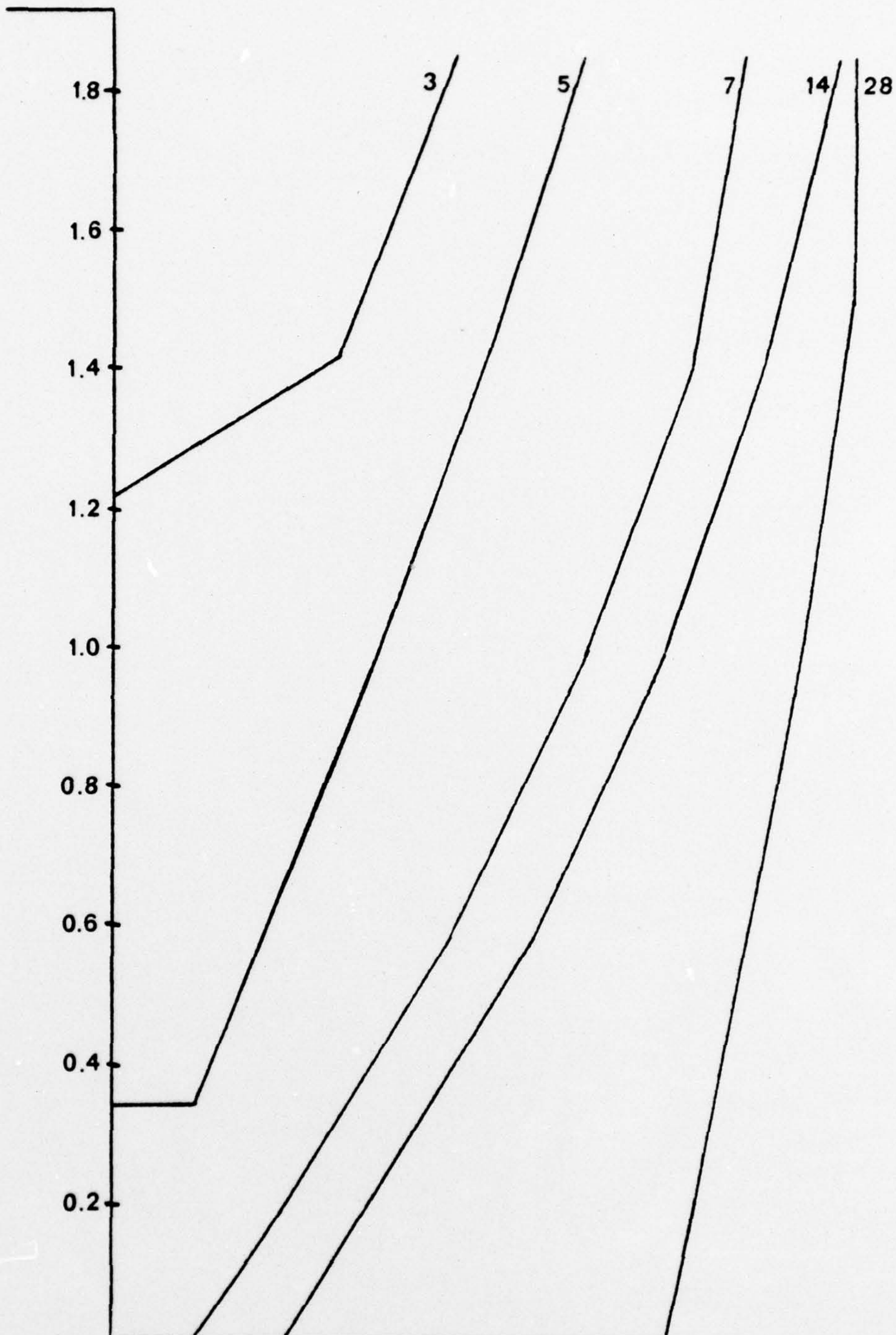


Figure 2 - XR-3 STARBOARD SIDEWALL CROSS SECTIONS (STATIONS AS INDICATED, UNITS IN FT.)

4. <u>Effect of Deadrise Angle</u>

From the previous discussion the surface effect ship's stability behavior is expected to be sensitive to the sidewalls' deadrise angle. In the XR-3 Loads and Motions Program listed in Ref. 2 the deadrise angle at the transom (78.8 deg) had been used for the computation of the deadrise forces. This calculation was implemented into subroutine SIDEWALL using the following statements:

```
      FYH(J)=-A22S*U*(V+XSS*R-ZS*P)
      •
      •
      CTNDR=0.0
      IF(DSS.LE.0.0) GO TO 22
      CTNDR=(ES-BB(1))/DSS
      IF(THETA.LT.0.0) CTNDR=0.39391
   22 CONTINUE
      FZHOLD(J)=FZH(J)
      FZHDRP(J)=PM1*FYH(J)*CTNDR*PROMO1
      FZH(J)=FZH(J)+FZHDRP(J)
      •
      •
      FK=(FZH(2)-FZH(1))*YSW+FKD-FY*ZS
```

The projection of the lateral force FYH(J) at each sidewall (J=1 for port, J=2 for starboard side) produced the respective component of vertical force FZH, where FZHDRP is the projected force and CTNDR is the cotangent of the deadrise angle. The roll angle had been already taken into account in the computation of DSS (draft at the stern). The factor PROMO1 simply provided a means to arbitrarily change the vertical projected force for studies undertaken in Ref. 2. The factor PM1 introduced the necessary sign change

in the sidewall force computation being dependent on the craft's side (PM1=-1 for port, PM1=+1 for starboard side). The roll moment FK was partly determined from the vertical forces of both sidewalls.

Comparing the deadrise angles given in TABLE V it is seen that the transom deadrise angle of 78.8 degrees is unique and the largest along each sidewall and no reason could be found why just the transom deadrise angle should be used for the vertical force computation. This fact rather came up when Leo and Boncal (Ref. 8) scaled down the simulation program of the 100-B testcraft to create the XR-3 Loads and Motions Program. For the 100-B testcraft the sidewall cross sections are uniformly shaped throughout most of its length. This uniformity does not occur for the XR-3, as shown in Figure 2. Therefore it has been supposed that another deadrise angle which is more representative for all angles existing along the XR-3 sidewalls, e.g. the deadrise angle at the center of gravity location (station 14), could possibly be more appropriate for the vertical force computation. To investigate the effect of this supposition, turn maneuvers in calm sea at 20 knots and various rudder angles have been simulated for both deadrise angles and lateral added mass coefficients.

TABLE VI

Steady State Roll Angle (deg) at 20 kn for various Rudder Angles (deg)

Rudder angle	Deadrise force computation at transom C_h=0.4	center of gravity C_h=0.4	center of gravity C_h=0.8	Experimental testcraft data (Ref.6)
5	0.52	0.32	0.29	0.09
9	1.07	0.78	0.72	0.28
12	1.50	1.15	1.11	0.58
15	1.98	1.53	unstable	1.36

Table VI shows the steady state values for the roll angle which are compared with those measured experimentally in 1974 and documented in Ref. 6. Since the XR-3 Loads and Motions Program under investigation represents the XR-3 craft configuration as it existed in 1974, Ref. 6 may serve to check whether the results produced by certain changes in the simulation program are favorable or not. It is not anticipated to exactly match the results obtained from the simulated runs to the measured values since for the testcraft data the following precisions for the measuring devices are stated in Ref. 6 : pitch and roll angle ±0.5°, rudder angle ±1.0° and speed ±1 kn. From TABLE VI it is obvious that the steady state values for roll angle using C_h=0.4 as the lateral added mass coefficient and the center of gravity deadrise angle for the vertical force computation are closer by 25 to 40 % to the measured angles than are the corresponding roll angles considering the transom deadrise angle.

Using the center of gravity deadrise angle and the lateral added mass coefficient C_h=0.8 as suggested in Ref. 3, the agreement in steady state roll angles could be improved by another 3 to 10 % for rudder angles up to 12 degrees. This improvement has also been reported in Ref. 3. Comparing the roll angle responses for turns generated by a 12 degrees rudder angle to port with C_h=0.4 (plots 21 and 22) and C_h=0.8 (plots 23 and 24) it is found that the smaller lateral added mass coefficient generates a little higher peak roll angle (1.47°) than does the larger coefficient (1.27°). Both responses show the same number of oscillations (eleven cycles) until they die out. The larger lateral added mass coefficient generates a small negative

roll angle shortly after the port rudder motion has been introduced. However, for a 15 degrees port rudder angle the simulation program showed an unstable response with increasing amplitudes of oscillation for pitch and roll angle (see plots 17 and 18). From this the lateral added mass coefficient being 0.8 does not seem to be appropriate for the XR-3 simulation if both sidewalls are considered for the vertical deadrise force computation. The effect of using both lateral added mass coefficients will be considered again in Sections III.D and E.

From TABLE VII it can be seen that the roll moments contributed by the bow seal (FKBS), plenum pressure (ABPB*PHI*Z), rudder (FKRUD) and sidewalls (FKSW) change the most. Comparing the effect due to the change from transom to center of gravity deadrise angle it is found that

- bow seal inward effect decreases

- plenum pressure outward effect decreases

- rudder inward effect decreases

- sidewall outward effect increases

= outward roll angle decreases.

The time histories for simulated turn maneuvers with 15 degrees port rudder angle using center of gravity and transom deadrise angle (TABLE VII) are shown in Appendix A as plots 13-16 and 9-12, respectively. Comparing these plots the effect of the change from transom to center of gravity deadrise angle and C_h=0.4 can be observed as

- pitch angle response being more damped

- roll angle response being more damped

- pitch and roll rate responses being more damped and having smaller peak values.

TABLE VII

Steady State Values for selected Deadrise Angles

20 kn Turn, calm Sea, 15 deg port rudder angle

Deadrise Angle (degrees)		Transom 78.8	C. of G. 58.5	arbitrarily 31.6	chosen 28.7
Pitch angle	(deg)	0.52	0.45	0.52	0.64**
Roll angle	(deg)	1.98	1.53	0.31*	- 0.33*
Draft	(in)	5.94	5.81	6.07	6.52
Speed	(kn)	19.27	19.37	19.1	18.7
FYSW		-824.0	-821.9	-810.0	-801.0
FYRUD		40.0	32.7	39.5	55.8
FYAED		- 19.5	- 20.0	- 19.1	- 17.6
R*V*AM		803.5	809.2	789.6	762.8
FKBS		-386.3	-336.4	- 68.4	71.6
FKSS		- 3.6	- 2.7	- 0.5	0.5
FKSW		202.0	212.1	175.0	184.0
FKRUD		-110.0	- 89.9	-108.4	-153.0
FKAED		- 53.5	- 56.0	- 52.4	- 46.2
FKP		0.19	0.14	0.03	- 0.03
ABPB*PHI*Z		351.9	273.5	54.6	- 57.2
FYH (P/S)		-39/-147	-45/-126	-78/-95	-107/-88
FYD		-637.8	-651.4	-637.3	-607.0

Note : * = still decreasing

** = still increasing, not quite steady state

The reason for the sidewall roll moment and thereby the net roll effect not changing more pronounced (TABLE VII) is that not only the lateral force FYH must be considered in order to determine the force F effecting roll stability (Sect. III.B.2, Fig. 1) but also the lateral drag force FYD has to be taken into account. Considering the XR-3 geometry using the center of gravity deadrise angle, as it is shown in solid lines in Fig. 3, the lateral force FYH can be seen to generate the vertical projected force FZHDRP and the force F, which is directed well above the center of gravity. But since FYD has to be added vectorially to the force F and its strength being several times larger than FYH (TABLE VII) the new resultant force F' determining the craft's roll behavior is directed well below the center of gravity (although F being directed above it). Thereby an outward roll angle is generated.

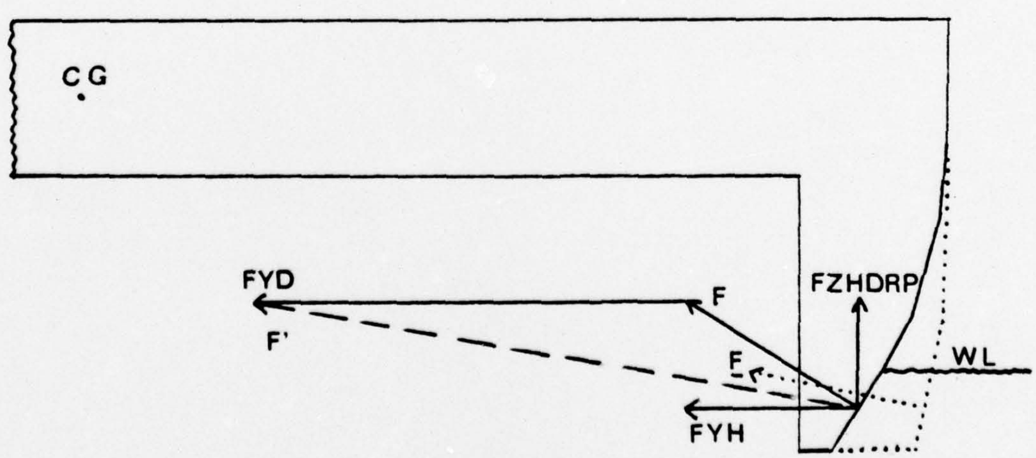


Figure 3 - DEADRISE AND DRAG FORCES IN A PORT TURN
(CG= CENTER OF GRAVITY, WL= WATER LINE)

Also from Fig. 3 the effect of considering the center of gravity versus the transom deadrise angle on the force generating the inward or outward roll moment can be seen. The center of gravity deadrise angle and its corresponding forces are shown in solid or dashed lines with F being directed above the center of gravity. The transom deadrise angle, shown in dotted lines, generates a force F̲ being directed below the center of gravity producing an outward roll moment which gets reinforced by adding vectorially FYD. From this the general stability check yields a smaller outward roll moment and angle using the center of gravity versus the transom deadrise angle. This is in agreement with the results given in TABLE VI.

Next, some simulation runs with arbitrary deadrise angles chosen such that small positive and negative steady state roll angles result are presented in order to, first, find out which deadrise angle would generate the moments necessary to simulate flat turns, and, second, verify the trend of the change in the respective moments which has been observed for the change from transom to center of gravity deadrise angle in TABLE VII. The value of the lateral added mass coefficient in these runs was 0.4 as it was in all runs listed in TABLE VII. Considering the roll moments over the range of deadrise angles from 78.8 to 28.7 degrees, the moments due to the bow seal, stern seal, propulsion and plenum pressure change consistantly in magnitude while those due to sidewalls, rudder and aerodynamics reach some extreme value and then increase again. Regarding the steady state roll angles listed in TABLE VII, it can be seen that the arbitrary chosen deadrise angles happen to be nearly symmetric about the deadrise angle that would generate zero roll angle (flat turn) under these simulation conditions. Keeping this symmetry in mind one finds that the values of the roll moments due to bow seal (FKBS), stern seal (FKSS), propulsion (FKP) and plenum pressure (ABPB*PHI*Z) are also

symmetric with respect to zero moments. For propulsion and plenum pressure the sign of the moments are identical to that of the roll angle while for bow and stern seal moments the signs are reverse. From the results given in TABLE VII with positive steady state roll angles Figure 4 has been drawn where the dotted line represents the craft's initial state, the dashed line represents the craft's steady state considering the transom deadrise angle and the solid line represents the craft's steady state (smaller roll angle) considering the center of gravity deadrise angle for the vertical force calculation. Same markings apply to the moment vectors shown from which their change in magnitude for both deadrise angles can be seen.

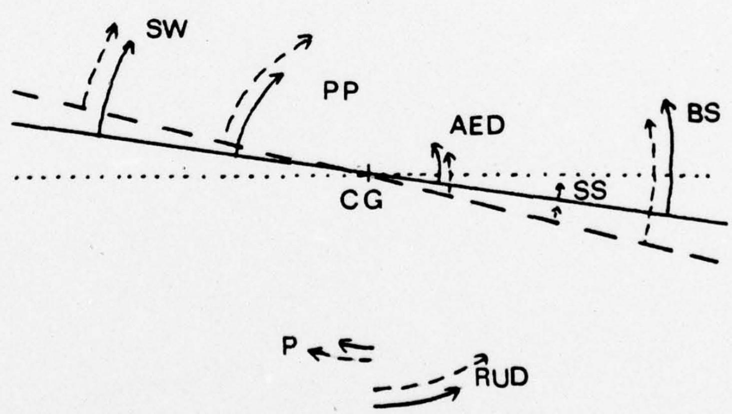


Figure 4 - ROLL MOMENTS IN A PORT TURN
(ROLL MOMENTS AND ANGLE NOT TO SCALE)

Legend:	AED Aerodynamic	CG Center of gravity
	BS Bowseal	PP Plenum pressure
	SS Sternseal	SW Sidewalls
	RUD Rudder	P Propulsion
	Deadrise angle:	- - - Transom
		——— Center of gravity

Since the simulation run with the center of gravity deadrise angle being used for the vertical force computation gave results that were more favorable (better damped time histories and steady state values closer to those measured experimentally) this change in vertical force computation was implemented into the XR-3 Loads and Motion Program. Starting with the deadrise angle given in Table V for draft up to seven inches, again straight line approximations for the effective deadrise angle at the center of gravity location (station 14) for larger drafts have been performed resulting in an almost linear relationship. This part of subroutine SIDEWALL is now valid for any draft and contains the following statements which have been used in this form for all simulation runs to follow in this study:

```
DDRANG=0.0
IF (DS.GT.0.5833) DDRANG=(DS-0.5833)*0.0629
DRANG=1.021+DDRANG-PM1*PHI
CTNDR=COTAN(DRANG)
FZHOLD(J)=FZH(J)
FZHDRP(J)=PM1*FYH(J)*CTNDR*PROMO1
FZH(J)=FZH(J)+FZHDRP(J)
•
•
FK=(FZH(2)-FZH(1))*YSW+FKD-FY*ZS
```

It should be noted that vertical projected forces from <u>both</u> sidewalls are used in computing the roll moments in the XR-3 Loads and Motions Program. Section III.E of this thesis will be concerned with the effect of changing the simulation program to consider the deadrise projected force only from the outward sidewall in a turn maneuver as it is discussed in Sect. III.B.2 .

C. CROSS-FLOW DRAG

In the preceding section the lateral force FYD which is due to cross-flow drag has been found to be rather large compared to FYH, thereby changing the direction of the resultant force significantly. FYD is computed in subroutine SIDEWALL by summing the contributions DF of all stations:

```
DF(I,J) = -HRHO*CDSW*VREL*ABS(VREL)*DSWAV(I,J)
```

where DF(I,J) is the lateral drag contributed by the j-th element of each (i-th) sidewall

HRHO is RHO/2.

VREL is relative velocity

DELX is the incremental distance used for the wetted draft calculation along each sidewall

DSWAV is the average wetted draft over one incremental distance

CDSW is the cross-flow drag coefficient for one sidewall .

The cross-flow drag coefficient being used in the present XR-3 Loads and Motions Program is the value corresponding to that for flow normal to a long flat plate being CDSW=1.28 . Ref. 3 points out that an investigation of cross-flow drag forces and coefficients (before the vertical added mass A33 had been reformulated as discussed in Sect. III.A.1) showed better agreement between theoretical and experimental results if CDSW=2.0, representing the normal drag coefficient for a sharp flat plate, had been used instead. After the reformulation of A33 the agreement between modified theory and experiment had very much improved, so

that the former drag coefficient could be used again. Since in this thesis work the change in A33s did not effect the roll behavior significantly (TABLE IV), some turn maneuvers at 20 kn and 15 degrees rudder angle have been simulated for various drag coefficients in order to investigate which CDSW would better match simulated and experimental steady state roll angle. From TABLE VII a decrease in roll angle and roll moment is desireable and therefore the cross-flow drag force FYD should be decreased via reducing CDSW. The steady state values are shown in TABLE VIII with the lateral added mass coefficient being unchanged C_h=0.4.

TABLE VIII

Steady state conditions for various CDSW

20 kn turn, 15 deg port rudder angle

CDSW	1.28	1.16	1.0	0.7
Pitch angle	0.43	0.43	0.44	0.46
Roll angle	1.55	1.48	1.38	1.14
Draft	5.78	5.80	5.83	5.91
Speed	19.39	19.36	19.31	19.19
FKBS	-343.0	-330.5	-308.1	-252.8
FKSS	- 2.7	- 2.6	- 2.4	- 2.0
FKSW	207.8	175.0	127.8	40.0
FKRUD	- 82.2	- 47.9	- 2.3	80.4
FKAED	- 56.6	- 58.7	- 61.6	- 67.6
FKP	0.14	0.14	0.13	0.11
ABPB*PHI*Z	276.4	264.6	246.5	201.9
FYH (P,S)	-43/-125	-45/-125	-48/-124	-57/-121
FYD	-654.9	-616.9	-561.0	-436.0

Comparison with Ref. 6 (Table VI) shows close agreement in roll angle (1.36°) for the run with CDSW=1.0 . But these

trial runs have been executed with arbitrary smaller drag coefficients because an increase in drag coefficient (e.g. CDSW=2.0 for sharp flat plate as in Ref. 3) would have enlarged the disagreement between simulated and experimental data. Also, from plot 29 for CDSW=1.28 and plot 31 for CDSW=1.16 it is seen that a smaller drag coefficient results in more damping in the roll response, in this case six versus nine cycles of distinguishable oscillations. Since the choice of CDSW=1.0 cannot be declared to be appropriate for the actual shape of the XR-3 sidewalls it will not be considered any further in this study. CDSW=1.16 generated a 4 % change (about 15 % is desired) toward the experimentally measured roll angle and its effect will be investigated together with the present cross-flow drag coefficient CDSW=1.28 in the studies to follow.

Shown below in Figure 5 is the dependence of steady state roll angle in turns generated by a 15 degrees rudder angle to port at 20 kn on the cross-flow drag coefficients used in the simulation runs (TABLE VIII).

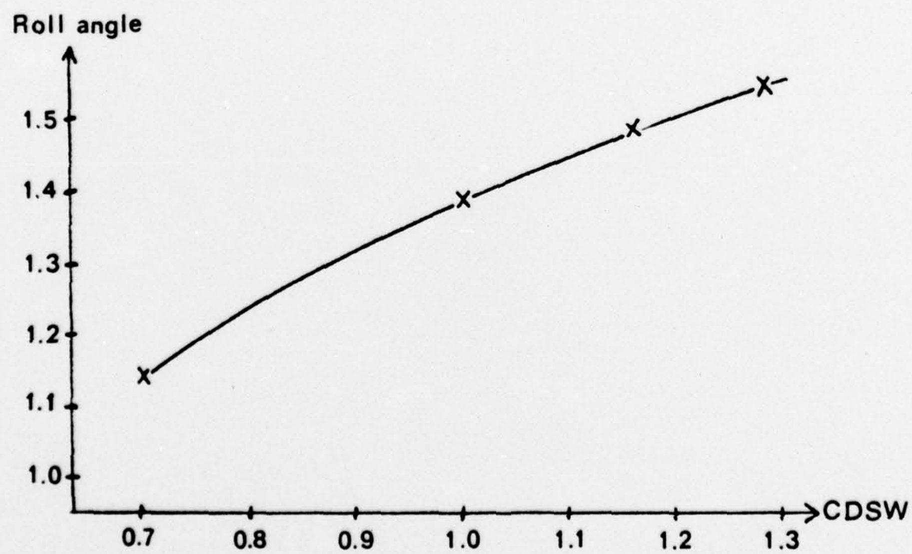


Figure 5 - S.S. ROLL ANGLE VERSUS CDSW

D. THRUST MAPPING

In turn maneuvers as they have been discussed in the preceding sections another important point to be considered is the change in thrust on both engines. Since the engines mounted on the XR-3 provide constant power for a given throttle setting, the actual thrust delivered during a turn maneuver may vary even though the throttle remains fixed. In all simulation runs shown in this thesis until now constant thrust has been used. In Ref. 6 experimentally measured reduction in thrust is given for turn maneuvers at 20 kn and various rudder angles. From this and Ref. 7 providing more detailed information the thrust-rudder dependence was as listed below.

<u>TABLE IX</u>
<u>Reduction in thrust for various rudder angles in turn maneuvers at 20 kn</u>

Rudder angle (deg)	total reduction in thrust (Ref. 6) (%)
5	- 2.8
9	- 3.3
12	- 4.3

TABLE IX has been used for thrust mapping (Block 16 of the data input) in the simulation runs. Due to unavailability of more precise data it has been assumed that the total reduction in thrust is contributed from both engines in equal amounts. But this may not be quite true, since due to the craft's roll angle a difference in immersion depth for both engines could result in unequal

changes in thrust. TABLE X shows the steady state values of these simulations considering two cross-flow drag coefficients, deadrise force contributions from both sidewalls computed at the center of gravity as well as both lateral added mass coefficients C_h=0.4 (0.8).

TABLE X

Steady state conditions using thrust mapping in 20 kn turns at various rudder angles

Rudder angle (deg)	Roll angle (deg) simulation	Roll angle (deg) Ref. 6	Speed (kn) simulation	Speed (kn) Ref. 6
CDSW=1.28				
5	0.30(0.25)	0.09	19.3(19.2)	19.8
9	0.71(0.61)	0.28	18.9(19.0)	19.5
12	0.99(0.89)	0.58	18.5(18.6)	19.2
CDSW=1.16				
5	0.28(0.23)	0.09	19.2(19.2)	19.8
9	0.67(0.57)	0.28	18.9(19.0)	19.5
12	0.94(0.84)	0.58	18.4(18.6)	19.2

Comparing the steady state roll angles obtained if thrust mapping is used with those listed in TABLE VI (no thrust mapping, deadrise force computation at the center of gravity), a change in roll angle by 6 to 14 % for C_h=0.4 and by 14 to 20 % for C_h=0.8 toward the measured angle can be observed. The steady state roll angles found in the simulation runs still differ from the roll angles given in Ref. 6 by a factor of about two and three but can be expected to be a little closer to these if proper thrust mapping, i.e. different maps for port and starboard engine, is used. By this also the steady state velocities which

differ by about 2.5 % can be expected to come in better agreement, i.e. to increase for smaller roll angles.

Regarding the roll angle time responses for simulation runs using both lateral added mass coefficients (0.4 and 0.8) and 12 degrees rudder angle the following characteristics have been found: the runs using thrust mapping (Table X, plot 33(35)) show almost the same transient behavior as do the runs without thrust mapping (Table VI, plot 21(23)) with about ten cycles of oscillation before the transients die out. But the runs using thrust mapping need quite a long time (t>45 sec) before they reach the steady state roll angle.

The effect of using a larger lateral added mass coefficient (0.8) can be observed in plot 35. Comparing this with plot 33, the roll angle response in plot 35 shows a smaller peak roll angle (1.25° versus 1.47°) and the transients have smaller amplitudes. But both die out after ten cycles. This effect has already been noted in Section III.B.4.

Investigating the effect of changing the coefficient CDSW=1.28 to 1.16 by comparison of the roll responses shown in plots 33 and 37 or 35 and 39, a significant damping effect as has been found previously in Section III.C can not be observed here.

E. DEADRISE FORCE OF OUTWARD SIDEWALL

This part of the investigation on how to effect the roll behavior of the testcraft simulation is again concerned with the deadrise angle.

In the present XR-3 Loads and Motions Program deadrise forces for both sidewalls are computed with the deadrise angle appropriately corrected by the roll angle for port and starboard sidewalls. The idea behind this, e.g. in a port turn, is to consider a pressure buildup (large FYH(S)) on the outboard side of the starboard sidewall and a reduction in pressure on the outboard side of the port sidewall (small FYH(P)). Thereby an upward vertical force FZHDRP (with negative sign) is obtained for starboard side, while a downward vertical force (positive sign) is computed for port side. Both vertical forces are then added to the buoyancy force of their side. The forces obtained by this approach are shown in Figure 6.

In Ref. 4, however, a different philosophy in regarding the acting forces is presented. As discussed in Section III.B.2 an approximate check on the craft's roll stability can be made if the SES geometry and the vertical location of its center of gravity are known (Fig. 1). In a port turn the principal force effecting the roll behavior arises from the <u>outboard</u> side of the starboard sidewall (relative high pressure on the structure there due to wave buildup) while there is only a small force (due to small pressure change) on the <u>inboard</u> side of the port sidewall contributing a roll moment only if there exists a roll angle. Now both vertical forces are directed upward. This approach and the resulting forces are shown in Figure 7.

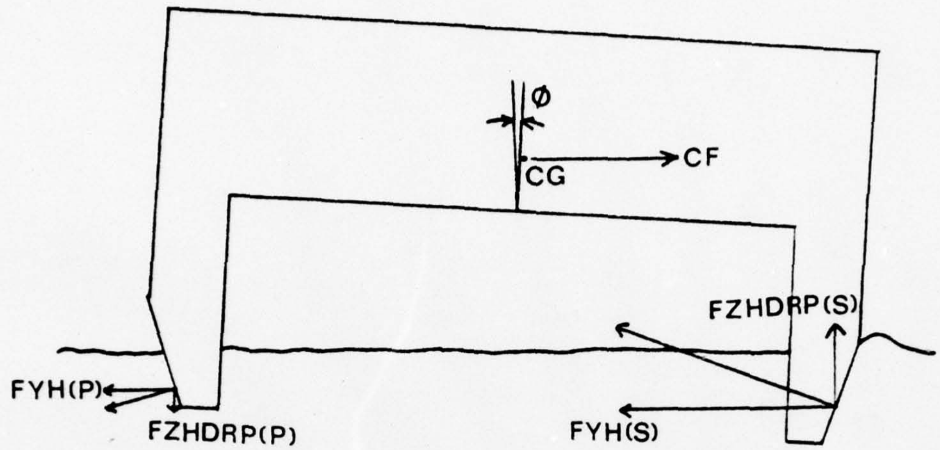


Figure 6 - ACTING DEADRISE FORCES (TWO SIDEWALLS)

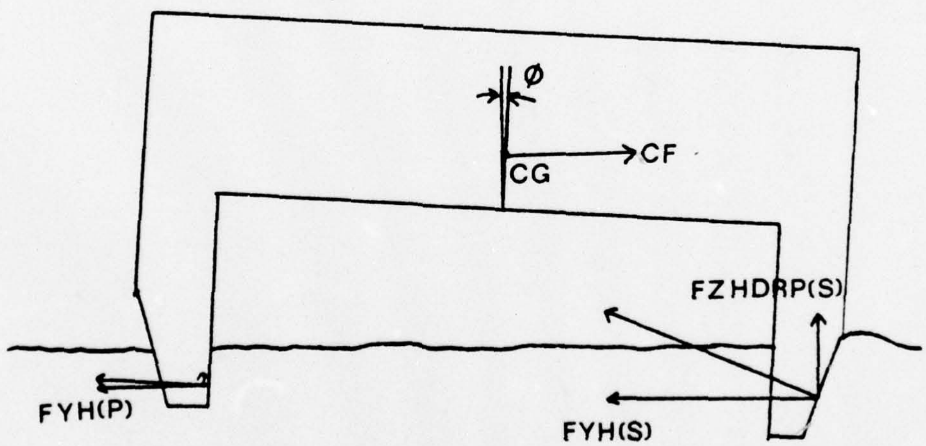


Figure 7 - ACTING DEADRISE FORCES (ONE SIDEWALL)

Note : Since the vertical force contributed by the inboard sidewall is rather small, as shown above, it can be neglected in the roll stability check (Sect. III.B.2).

To investigate the effect of this interpretation of the acting forces two statements controlling the computation of deadrise forces via the sign of the rudder angle RUDANG (port rudder is positive) and the sidewall under investigation (PM1=-1 for port side) have been added to the computation procedure for the vertical projected force :

```
DDRANG=0.0
IF (DS.GT.0.5833) DDRANG=(DS-0.5833)*0.0629
DRANG=1.021+DDRANG-PM1*PHI
CTNDR=COTAN(DRANG)
RUDSIG=SIGN(1.,RUDANG)
IF(RUDSIG.NE.PM1) CTNDR=PM1*TAN(PHI)
FZHOLD(J)=FZH(J)
FZHDRP(J)=PM1*FYH(J)*CTNDR*PROMO1
FZH(J)=FZH(J)+FZHDRP(J)
```

The steady state values for simulated turn maneuvers using thrust mapping and center of gravity deadrise angle are shown below considering two cross-flow drag coefficients and both lateral added mass coefficients C_h=0.4(0.8).

TABLE XI

Steady state conditions in 20 kn turns at various rudder angles

Rudder angle (deg)	Roll angle (deg) simulation	Roll angle (deg) Ref. 6	Speed (kn) simulation	Speed (kn) Ref. 6
CDSW=1.28				
5	0.43(0.52)	0.09	19.4(19.5)	19.8
9	0.90(1.00)	0.28	19.1(19.4)	19.5
12	1.22(1.34)	0.61	18.7(19.0)	19.2
CDSW=1.16				
5	0.41(0.51)	0.09	19.3(19.5)	19.8
9	0.87(0.98)	0.28	19.1(19.3)	19.5
12	1.17(1.30)	0.61	18.6(19.0)	19.2

Comparing the steady state values for simulated runs in tables X and XI , the effect of using only the outward sidewall for the deadrise force computation can be observed to give less favorable (little larger) steady state roll angles but more favorable (larger) steady state velocities. This is exactly what has been expected since, as shown in Figures 6 and 7, if deadrise force contributions from both sidewalls are used, the deadrise force from the port sidewall will reinforce the one from the starboard sidewall toward a less outward roll moment (Fig. 6) while applying the philosophy depicted in Fig. 7 the vertical force from the port sidewall counteracts the starboard deadrise force.

Regarding the roll angle responses shown in Appendix A for 12 degrees rudder angle with CDSW=1.28 (plots 41 and 43) and CDSW=1.16 (plots 45 and 47) and comparing these with the corresponding ones from the previous section (plot 33, 35 and 37, 39) the change in the vertical force computation considering the outward sidewall only is seen to result in about 8 versus 10 cycles of transient oscillations with less amplitude. Using $C_h=0.8$ (plots 43 and 47) has a quite significant damping effect and makes the roll angle response more resemble a step, which is in accordance with the experience gained by Ref. 7. Also, comparing these plots with plots 35 and 39, the negative roll angle occurring at the moment when the rudder has been introduced does not show up any more.

F. VERTICAL LOCATION OF CENTER OF GRAVITY

In Section III.B.2 it was discussed how to check for the testcraft's roll bahavior in a turn provided the SES geometry and the location of the center of gravity are known. This section will be concerned with the effect of different vertical locations of the center of gravity on the simulated XR-3 roll behavior

From experimental measurement the location of the center of gravity of the XR-3 has been determined to be 10.05 ft forward of the transom and Leo and Boncal established the vertical location at 2.54 ft above the keel on the longitudinal center line of the craft. As modifications to the testcraft were introduced (e.g. engines and seals) the horizontal location of the center of gravity was again established experimentally. No such changes were made on the vertical location. In order to investigate the sensitivity of the steady state roll angle to vertical locations of the center of gravity, reductions in height (in accordance with the stability check geometry depicted in Figure 1) in increments of 0.1 ft were entered into the Loads and Motion Program.

Simulation runs with constant thrust and initial speed of 20 kn introducing a 15 degrees port rudder angle, deadrise force contributions from both sidewalls computed at the center of gravity, the sidewall drag coefficient CDSW=1.28 and the lateral added mass coefficient being 0.4 were executed and the results are shown in Table XII. From the listed data it follows that with a lower vertical location of the center of gravity a tendency toward an inward roll angle (here actually a smaller outward roll

angle) can be achieved. As shown, a decrease in vertical distance by 0.1 ft resulted in about 0.1 degree decrease for both peak and steady state roll angle (almost linearly related). From the corresponding plots as indicated in Table XII a roll damping effect due to the relocation of the center of gravity can hardly be recognized. The number of cycles of transient oscillations and the steady state speed were about the same for all runs listed in Table XII.

TABLE XII

Roll conditions in 20 kn turn with constant thrust and 15 degrees port rudder angle

	vertical location of CG 2.54	2.44	2.34	2.24	experimental testcraft data
steady state roll angle	1.55	1.43	1.32	1.22	1.36
peak roll angle	1.67	1.53	1.46	1.35	
peak roll rate	2.13	2.07	1.98	1.91	
cycles of transients	8	8	8	8	
refer to plots	13-14	49-50	51-52	53-54	
steady state speed	19.4	19.3	19.3	19.3	18.7

Table XIII shows the effect of changing the vertical location of the center of gravity for simulation runs at 20 kn with 12 degrees port rudder angle and thrust mapping applied, deadrise force computation for both sidewalls at the center of gravity and the coefficients being 0.4 for the lateral added mass and CDSW=1.28 for the sidewall drag. These conditions were similar to those used in Table X.

From Table XIII the effect of reducing the vertical location of the center of gravity in 0.1 ft increments over a reasonable range can be observed to also result in linear reductions in maximum and steady state roll angle for the case if thrust mapping is used. Nonlinear reductions appear for the peak roll rate. The number of cycles during the transient period (ten) is again not effected by the vertical relocation of the center of gravity. Regarding the corresponding plots a very slight damping effect can be observed for reduced vertical locations. The results given in Table XIII are graphically represented in Figure 8 .

TABLE XIII

Roll conditions in 20 kn turn with thrust mapping and 12 degrees port rudder angle

	vertical location of CG				experimental
	2.54	2.44	2.34	2.24	testcraft data
steady state roll angle	0.99	0.91	0.84	0.77	0.58
peak roll angle	1.47	1.36	1.25	1.16	
peak roll rate	2.14	1.92	1.74	1.58	
cycles of transients	10	10	10	10	
refer to plots	33-34	55-56	57-58	59-60	
steady state speed	18.5	18.4	18.4	18.4	19.2

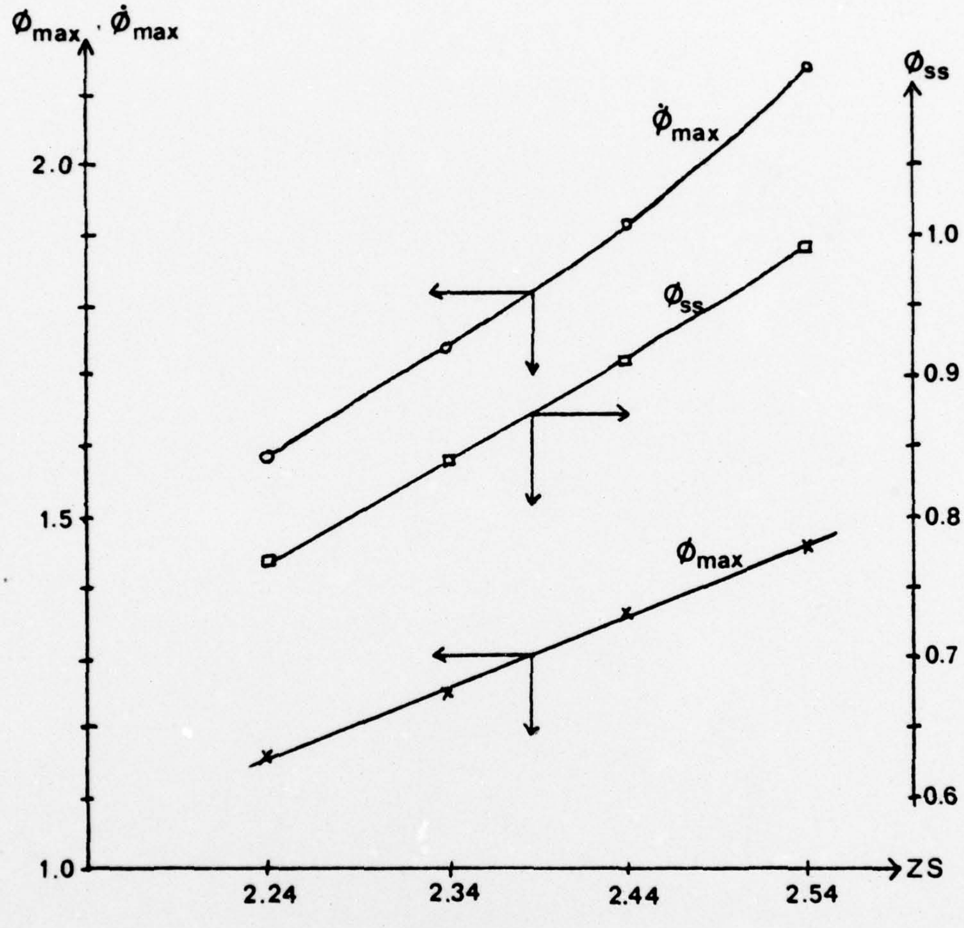


Figure 8 - ROLL CONDITIONS VERSUS VERTICAL LOCATION OF CENTER OF GRAVITY (TABLE XIII)

G. ROLL DAMPING DUE TO VERTICAL WAVE GENERATION

One part of subroutine SIDEWALL is concerned with the roll damping effect which is due to vertical wave generation during a roll motion. The computation of the roll damping term was developed by Oceanics Inc. and added to the program by Menzel [Ref. 2]. The principles used in the development of this addition were not provided by Oceanics Inc., however, the apparent idea is to reduce the computed roll moment FK by some value which is dependent on the craft's roll rate and its draft, thereby on the vertical added mass A33. During the study of the effect of these additional terms a discrepancy was noted in the dimensions used in the calculations.

The roll moment FK is calculated by the equation given in SDWL1950 and considering the expressions leading to this statement it is found that

dim [FK] = lb . ft

which is the correct dimension for a moment vector. Now considering the dimension of the roll damping term

dim [PROMO2*YSW*YSW*BC2*P/PI]

which is subtracted from FK (SDWL2200) it is found

PRCMO2 and PI are dimensionless
dim [YSW] = ft
dim [P] = rad/sec
dim [BC2] = dim [AC2]
= dim [FC2 * length]
= dim [F2 * cos(x) * length]
= dim [A33 * length]

= dim [RHO * B * B * length]

= (lb . sec^2 /ft^4) . ft . ft . ft .

So for the roll damping term

dim [YSW * YSW * P * BC2]

= ft^2 . (rad/sec) . (lb . sec^2/ft^4) . ft^3

= lb . ft . sec

which is not the correct dimension for a moment expression. Assuming that only the given terms may be involved in the roll damping calculation, it is possible to come up with the proper dimension if the roll rate P were squared but keeping its sign, thus getting

roll damping term = PROMO2*YSW*YSW*BC2*P*ABS(P)/PI .

Also the vertical added mass should be associated with some 'velocity squared' - expression which is absent in the original version of this part of the program but could be generated by squaring the roll rate P. The effect of the modified expression will be an increase in the damping effect for roll rates P>1.0 which exist only in the initial phase of the turn maneuver (maximum roll rate in all simulation runs was about 2.0) . But for most of the run length P is less than unity and the supposed modification will decrease the damping effect especially when approaching steady state (P=0.0) .

The PROMO2 - term provides a means to arbitrarily set a roll damping factor which, as stated in Reference 2, has been found from experiments to be 16.0 . Until now PROMO2=1.0 has been used in this thesis work. So the effect of changing it to the experimental value is investigated next. In the runs to be discussed turn maneuvers at 20 kn with a 12 degrees port rudder angle have been simulated with deadrise forces being computed at the center of gravity, using the experimental damping factor PROMO2=16.0 and the

coefficients CDSW=1.28 for the sidewall drag and C_h=0.4 for the lateral added mass.

1. Thrust is held constant with deadrise force contributions from both sidewalls

Comparing the obtained plots 61-62 with plots 21-22 (PROMO2=1.0) only a slight damping effect on roll angle response can be observed (peak roll angle 1.45° versus 1.47°), but the number of transient oscillations decreases from eleven to nine. The peak roll rate decreased from 2.14 to 2.10 for PROMO2=16.0 and the damping effect is more pronounced in the roll rate time history.

2. Thrust is mapped with deadrise force contributions from both sidewalls

Comparing the plots 63-64 with the corresponding ones (33-34) for PROMO2=1.0 , again only a slight damping effect can be noticed. The peak roll angle is again reduced from 1.47 to 1.45° and the number of cycles of transient oscillations is uneffected.

If the damping term is changed to include the P*ABS(P) expression (plots 65-66) there result eleven versus nine cycles of transient oscillations with little higher amplitudes (peak roll angle is again 1.47° as it was for PROMO2=1.0) . The roll rate time history also shows little larger amplitudes (peak roll rate is 2.14 versus 2.10) .

3. Thrust is mapped with deadrise force contribution from the outward sidewall only and lateral added mass coefficient C_h=0.8

Comparing these plots (67-68) for PROMO2=16.0 with plots 43-44 where PROMO2=1.0 again only a slight damping effect in roll angle response can be noticed with the number of

transient oscillations being uneffected. Using the P*ABS(P) term the slight damping effect shown in plot 67 is cancelled as shown in plot 69.

The above observations show that the experimentally determined roll damping factor PROMO2=16.0 has only a negligible damping effect. Considering the roll damping term again as it was added to the present XR-3 Loads and Motions Program in 1974, there was a 1/PI - factor which actually cancelled the PI - factor contained in the former expression for the vertical added mass A33S (Section III.A). Since the PI - factor already has been eliminated by correcting the A33S - expression, there is no further need to cancel it in the damping term by the 1/PI - term which therefore also could be eliminated. This change is expected to cause an increase in sidewall roll damping by a factor of PI and has been investigated by an additional run.

4. Thrust is mapped with deadrise force contribution from the outward sidewall only, roll damping term being

   16.0*YSW*YSW*BC2*P

   and lateral added mass coefficient C_h=0.8

From plots 71-72 again only a slight damping effect versus plots 67-68 can be noticed.

The investigation described in this section shows that the roll damping due to vertical wave generation as included in subroutine *SIDEWALL* is not very effective even if the factor PROMO2 in the damping term is increased from 16.0 to 50.0 . There also is a lack in matching dimensions (statement SDWL2200).

IV. PROPULSION AND RUDDER SUBROUTINES

In all simulation runs executed during this study the XR-3 Loads and Motions Program as given in Ref. 2 has been used except for the modifications mentioned in this work. This simulation program contains Forbes' version [Ref. 9] of 'SUBROUTINE PROP' which included some revisions of the original version given by Leo and Boncal [Ref. 8]. Since in TABLE VII (Section III.B.4) the roll moment contributed by the propulsion system (FKP) is rather small (0.1 to 0.2) an additional run using Leo and Boncal's version has been executed under the conditions as stated for TABLE VII (center of gravity deadrise angle). The steady state values are shown below (in parantheses are the values obtained using Forbes' version) :

pitch angle	0.44(0.45)	draft	5.73(5.81)
roll angle	1.67(1.53)	speed	19.39(19.37)
FYSW	-909.4(-821.9)	FYRUD	- 54.7(32.7)
FYAED	- 21.3(- 20.0)	R*V*AM	888.4(809.2)
FYP	97.0(0.0)		
FKBS	-348.0(-336.4)	FKSS	- 3.0(- 2.7)
FKSW	269.9(212.1)	FKRUD	150.3(- 89.9)
FKAED	- 63.5(- 56.0)	FKP	-305.2(0.14)
ABPB*PHI*Z	299.5(273.5)		
FYD	-729.2(-651.4)	FYH (P/S)	-43/-137(-45/-126)

Regarding these values drastic differences are found for FYP and FYRUD as well as for FKP and FKRUD, though the steady state values for pitch and roll angle, draft and speed are close to those obtained using Forbes' version. The pitch and roll angle responses are given in plots 25-28. Comparing these with the corresponding ones using Forbes' version (plots 13-16) it is seen that Leo and Boncal's version generates more oscillatory roll and pitch angle responses. Therefore a review of subroutine PROP especially the computation of the respective forces and moments has been carried out and are discussed below.

The review resulted in force and moment equations which are identical to those given by Leo and Boncal [Ref. 8]. Another point that supports the supposition to use this version of subroutine PROP is the fact that it provides a reasonable roll moment due to the propulsion system (Forbes' version provides almost zero roll moment). In order to test the effect of changing subroutine PROP to its original form, simulation runs 1. and 2. from the preceding section have been repeated and their time histories for the roll behavior are shown in plots 73-74 and 75-76, respectively. Comparing these with the corresponding ones using Forbes' version of subroutine PROP, plots 61-62 and 63-64, it is observed that the steady state and peak roll angles are larger by about 7 % and the number of transient oscillations is uneffected by this change.

Next a review of subroutine RUDDER has been carried out in order to investigate the cause of the change in sign for FYRUD and FKRUD depending on the propulsion subroutine used (Forbes' or Leo and Boncal's version) although identical RUDDER-subroutines have been used in both cases. The important equations to be considered are :

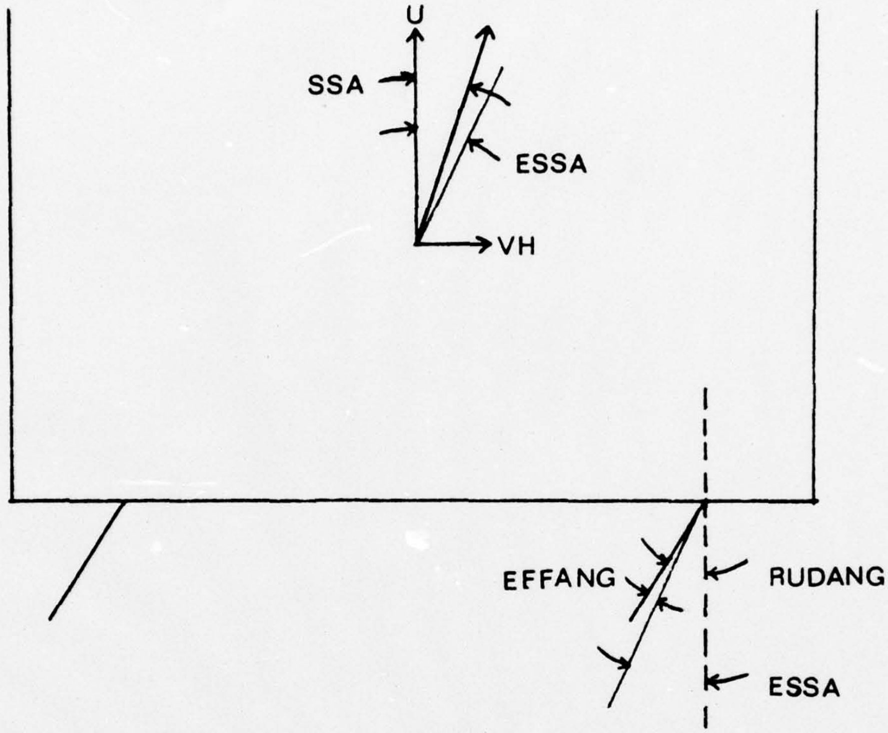
```
DSR=Z+ZS-XR*THETA
ENDFAC=1. + DSR/(DSR+RSPAN)
VH=V + XR*R - ZR*P
EFFANG=RUDANG - ENDFAC*VH/U
FY=RHO*U*U*RAREA*ENDFAC*RCLB*EFFANG
•
FK= -ZR*FY
```

The above equations compute

- draft at the rudder location
- endfactor depending on the rudder length below the craft's keel
- sideslip velocity
- effective rudder angle depending on the craft's forward and sideslip velocities
- lateral force depending on rudder area and effective rudder angle
- roll moment due to rudder .

The sign of the roll moment FK is dependent on the sign of the lateral force FY which depends on the sign of the effective rudder angle EFFANG. This in turn depends of course on the introduced rudder angle, but the magnitude of the second term of this equation (sideslip angle) is responsible for the actual sign of EFFANG. VH/U represents the tangent of the sideslip angle which - applying small angle approximation - is subtracted from the introduced rudder angle (see Figure 9). Since ENDFAC=1.73 and U was the same for both runs, a difference in VH which was larger in Leo and Boncal's version by about 50 % caused the negative sign (versus a positive sign using Forbes' version) for the effective rudder angle EFFANG and thereby FY. So the only way to introduce a change toward an inward roll behavior here (FKRUD was positive) is to first check the input value for RSPAN and second to eventually modify the craft's engines to have larger immersion into the water.

With regard to the first item, if RSPAN would increase, ENDFAC would decrease as would the magnitudes of EFFANG (negative), FY (negative) and FK (positive).



SSA = VH/U	sideslip angle
ESSA=ENDFAC*VH/U	effective sideslip angle
RUDANG	rudder angle
EFFANG	effective rudder angle

Figure 9 - EFFECTIVE RUDDER ANGLE IN A TURN MANEUVER

Considering next the fact that the engines of the XR-3 had been replaced in 1976 a recent measurement of the rudder and propeller location yielded the following data (original input values shown in parantheses) :

XPO = -1.50 (-1.275)
ZPO = -1.333 (-0.604)
XRO = -1.083 (-1.125)
RSPAN= 1.333 (1.21)
RAREA= 1.42 (0.68)

Two of the runs discussed in the preceding section have been repeated using the original roll damping term and the new propulsion and rudder input parameters.

1. Thrust is mapped with deadrise force contributions from both sidewalls with C_h=0.4 .

Comparing plots 77-78 with the corresponding ones for the former rudder and propulsion parameters (plots 63-64) the expected effect due to a decrease in FKRUD can be observed resulting in smaller peak roll angle (1.34° versus 1.45°) and a significantly decreased steady state roll angle (0.65° versus 0.99° at t=50 sec). The transient period of the roll angle response in plot 77 shows the same number of transient oscillations as plot 63 but the response did not reach steady state even after 45 sec. The steady state roll angle could be estimated to be about 0.3 to 0.4 degrees.

2. Same conditions as in the previous run but with deadrise force contribution from the outward sidewall only and C_h=0.8 .

Regarding plots 79-80 versus plots 71-72 a similar effect as mentioned before is observed. Now the roll angle response shows a more oscillatory transient period. The peak roll angle reduced from 1.46 to 1.36 degrees while the roll angle at t=50 sec changed from 1.34 to 0.97 degrees. For this run the steady state roll angle could be estimated to be about 0.8 degrees since the roll angle response again did not reach steady state for the run using the recently determined rudder and propulsion parameters. The initial small negative roll angle which appeared in the previous run (plot 77) at the moment when the rudder motion is introduced, does not show up any more. The overall roll response shown in plot 79 does not fall off as steeply (compared to plot 77) if, in a turn maneuver, deadrise force contribution from the outward sidewall only is considered.

From these runs it is obvious that the rudder and propulsion parameters of the new engines result in a more favorable XR-3 roll behavior with a significantly less steady state outward roll angle. At the time of this sensitivity study Reference 7 pointed out that there actually is no roll angle indicated by the measuring devices in a port turn at 20 knots and 12 or 15 degrees rudder angle. Keeping the device sensitivity of ±0.5 degrees in mind, it can be concluded that the steady state roll angle provided by the present XR-3 Loads and Motions Program including the before mentioned program modifications by the author, is quite well in agreement with the actual craft data. Further efforts should be undertaken to obtain a better damping effect during the transient period.

Remark :

Although the new engines extend about 0.5 ft deeper into the water than the old engines, the new input value for RSPAN is close to the former value. In Reference 1 the denominator of the second term in the equation for ENDFAC is defined to be the distance from the water surface to the bottom tip of the rudder. The equation for ENDFAC used in the present program accounts for changes in draft DSR in both the numerator and the denominator. The RSPAN-term should then be defined to be the distance from the craft's keel to the bottom tip of the rudder. The author suspects that formerly there has been chosen too large a value for RSPAN in the case of the old engines (RSPAN=1.21 ft, probably from water surface to bottom tip of the rudder). Since the bottom tip of the rudder and the center of the propeller were located at almost the same distance from the craft's keel the magnitudes of ZPO and RSPAN should be about the same which is not true for the former chosen values. From these observations the author concludes that until now a too optimistic roll behavior resulted due to a too large value for RSPAN.

V. CONCLUSIONS AND RECOMMENDATIONS

The preceding sections of this chapter reflect the results of an investigation on how the XR-3 roll behavior in turn maneuvers at 20 kn simulated with the Loads and Motions Program is affected by certain changes in parameters and forces. The results of this sensitivity study are summarized as follows :

* Added mass effect

A reformulation of the vertical added mass computation which reduced the A33s-value by a factor of 1/PI had only a little effect in changing steady state draft, pitch angle and required thrust for constant speed in straight runs. In turn maneuvers this change resulted in less damped responses for pitch and roll angle and affected the steady state values for pitch angle by +8.3 % , roll angle by -1.0 % and draft by +1.4 % . Considering the roll behavior, the effect of reducing the A33s-value by a factor of 1/PI in the vertical added mass computation was negligible.

A change in the lateral added mass coefficient C_h=0.4 to 0.8 had the effect of reducing the amplitudes of the transient oscillations and the steady state roll angle by 0.1 degree toward the experimentally measured value. Since in a turn maneuver with 15 degrees rudder angle an unstable craft behavior showed up which had not been experienced in practice, the value of C_h=0.8 is not realistic if deadrise force contributions from both sidewalls are considered. If deadrise force contribution from the outward sidewall only

is used in the simulation program the increase in lateral added mass coefficient causes an increase in the steady state roll angle by about 0.1 degree. But since now the roll angle response is quite significantly damped and resembles a step as it does in practice, the choice of the larger coefficient (0.8) seems to be appropriate for the case of the deadrise force contributed from the outward sidewall only.

* Deadrise angle effect

The deadrise angles over the length of the curved XR-3 sidewalls are not uniform. Changing the deadrise angle which is used in the deadrise force computation from the transom (78.8^{o}) to the center of gravity (58.5^{o}) resulted in more damped responses for pitch and roll motion in turn maneuvers. For all chosen rudder angles generating port turns at 20 kn the steady state roll angle changed favorably by 23 to 38 % toward the corresponding roll angle measured experimentally and documented in Ref. 6.

* Cross-flow drag coefficient

Changing the cross-flow drag coefficient (CDSW=1.28 for a long flat plate) to lower values, e.g. CDSW=1.00 , the testcraft's simulated roll behavior could be forced to match the measured steady state values. But since this coefficient has been chosen arbitrarily and cannot be declared to be appropriate for the actual XR-3 sidewalls (CDSW=1.0 means that there is no effective drag coefficient) this CDSW-value has not been considered any longer. Another suggested cross-flow drag coefficient CDSW=1.16 [Ref. 3] resulted in about 5 % reduction in steady state roll angle and a shorter transient period (about 20 %) with smaller amplitudes of oscillation than did the runs using CDSW=1.28.

* Thrust mapping

Performing thrust mapping in the simulation runs using the data provided in Ref. 6 and assuming that both engines lose equal amounts of thrust in turn maneuvers, the simulated steady state roll angles could be shown to agree better with the measured angles by about another 10 % but the roll angle response did not quite reach steady state even after 45 seconds.

* Deadrise force from outward sidewall only

The simulation runs executed with the deadrise force computed for the outward sidewall only and thrust mapping as done before, showed less agreement for both C_h=0.4 (0.8) with the corresponding measured steady state roll angles than did the runs considering deadrise forces from both sidewalls. But for C_h=0.8 the roll angle response was significantly damped and looked more like a step, as was experienced in practice.

* Vertical location of the center of gravity

The given value for the vertical location of the center of gravity (2.54 ft above the keel) might not be quite correct due to the difficulties in experimentally determining it. The significant effect of the vertical center of gravity location on the XR-3 roll behavior is obvious from Figures 1 and 8 and the discussion in Section III.F. Since it controls exceedingly the XR-3 roll behavior it is important that future investigators obtain an accurate measurement of the C.G. location before taking testcraft data.

* Subroutine PROP

A review of the propulsion subroutine revealed that the force and moment calculations as given by Leo and Boncal (Ref. 8) should be used instead of the version stated by Forbes (Ref. 9). This change results in a 7 % larger outward steady state roll angle but it provides a reasonable roll moment due to the propulsion system.

* Roll damping due to vertical wave generation

The roll damping calculation included in subroutine SIDEWALL has only a negligible effect on the craft's net roll behavior over the range of the damping factor 1.0<PROMO2<50.0 . Since there also is a discrepancy in the dimension of the roll damping term the source of this part of the program should be investigated.

* Suggested areas for further investigation

During the studies undertaken with the XR-3 Loads and Motion Program the author found the following points either in the input data from the testcraft or in the program that require further investigation :

- Rudder/thrust angle

As learned from Ref. 7 the rudder/thrust motion is directly introduced to the port engine while the starboard engine follows this via a metal bar connecting both engines. The starboard rudder and thrust vector may be off by 2 or 3 degrees to either side, depending on the direction of the rudder/thrust action. Thereby the roll behavior will certainly be effected. Since rudder/thrust mapping is available in the Loads and Motion Program, it is important that accurate data be collected for each engine during a test run.

■ XR-3 weight

During each test run there is a possibility that the weight is not exact since, as learned from Ref. 7, the testcraft takes on water in the seals and thereby its weight increases causing larger draft which also effects the roll behavior. This additional weight can be substantial and attempts should be made to measure or estimate the additional weight to be used in the Loads and Motion Program.

■ Cross-flow drag coefficient

Further efforts should be undertaken to establish the proper value of the cross-flow drag coefficient since CDSW=1.28 might not be quite appropriate for the actual shape of the XR-3 sidewalls.

■ Sideslip velocity

Those parts of the Loads and Motions Program where terms contributing to the lateral velocity V are computed should be reviewed since a large value of V may result in a change in the effective rudder angle from positive to negative.

In this sensitivity study it has been shown that the most significant effect on the simulated XR-3 roll behavior are contributed by

* deadrise angle
* vertical location of the center of gravity
* rudder and propeller location .

Less significant effects are contributed by

* thrust mapping
* cross-flow drag coefficient .

For further studies concerned with the XR-3 Loads and Motions Program for improved roll behavior representation it is recommended to use

- the reformulated equation for the vertical added mass A33

- deadrise angle at the center of gravity location

- deadrise force contribution from the outward sidewall only

- subroutine PROP as given by Leo and Boncal and in Appendix C of this thesis

- thrust and rudder mapping.

APPENDIX A

PLOTS

In the table given below are listed all plots with the respective parameters used in the corresponding simulation run. The table contains the following abbreviations :

COEF	coefficient	CG	center of gravity
CDSW	sidewall drag	C_h	lateral added mass coef.
ch4	chapter IV		
DRANG	deadrise angle	DF16	PROMO2=16.0
PA	pitch angle	PR	pitch rate
RA	roll angle	RR	roll rate
REFTAB	refer to table	RUDANG	rudder angle
TR	Transom		

L-B Leo and Boncal's version of subroutine 'PROP' used

P*\|P\| or P*PI P replaced by ... in SDWL2200 (Section III.G)

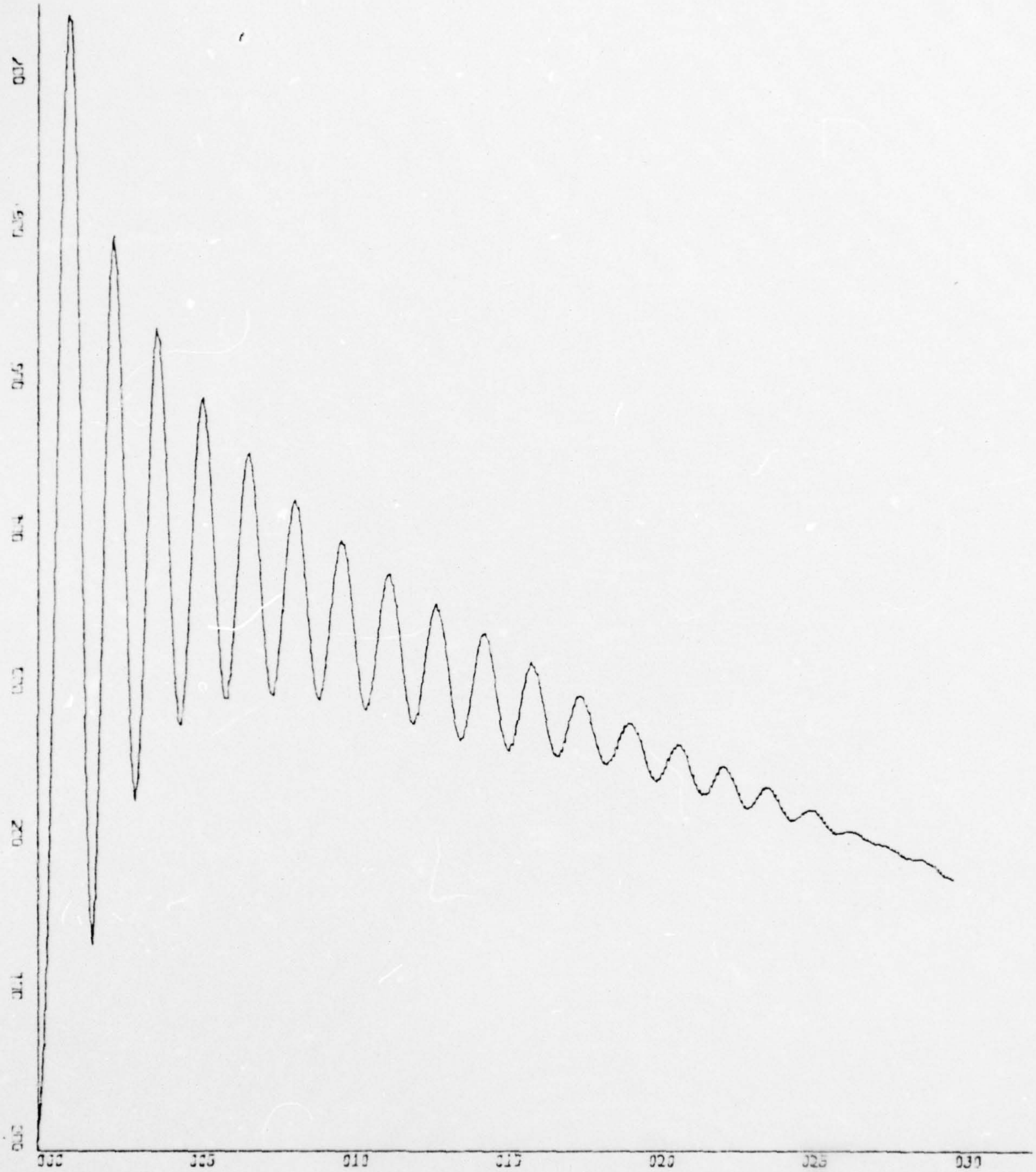
ZS-0.1 vertical location of CG is 2.54 - 0.1 (ft)

PLOT NO	REF TAB	RESP	RUD ANG	DR ANG	COEF C_h	COEF CDSW	THRUST MAP	SDWL-FORCES	REMARK
1	1	RA	35	TR	0.4	1.28	no	both	no PBAR
2	1	PA	35	TR	0.4	1.28	no	both	
3	1	RA	35	TR	0.4	1.28	no	both	with PBAR
4	1	PA	35	TR	0.4	1.28	no	both	
5	4	RA	15	TR	0.4	1.28	no	both	old A33s
6	4	PR	15	TR	0.4	1.28	no	both	
7	4	PA	15	TR	0.4	1.28	no	both	
8	4	PR	15	TR	0.4	1.28	no	both	

PLCT NO	REF TAB	RESP	RUD ANG	DR ANG	COEF C_h	COEF CDSW	THRUST MAP	SDWL-FORCES	REMARK
9	4,6	RA	15	TR	0.4	1.28	no	both	
10	4,6	RR	15	TR	0.4	1.28	no	both	
11	4,6	PA	15	TR	0.4	1.28	no	both	
12	4,6	PR	15	TR	0.4	1.28	no	both	
13	6	RA	15	CG	0.4	1.28	no	both	
14	6	RR	15	CG	0.4	1.28	no	both	
15	6	PA	15	CG	0.4	1.28	no	both	
16	6	PR	15	CG	0.4	1.28	no	both	
17	6	RA	15	CG	0.8	1.28	no	both	
18	6	RR	15	CG	0.8	1.28	no	both	
19	6	RA	12	TR	0.4	1.28	no	both	
20	6	RR	12	TR	0.4	1.28	no	both	
21	6	RA	12	CG	0.4	1.28	no	both	
22	6	RR	12	CG	0.4	1.28	no	both	
23	6	RA	12	CG	0.8	1.28	no	both	
24	6	RR	12	CG	0.8	1.28	no	both	
25	ch4	RA	15	CG	0.4	1.28	no	both	L-B
26	ch4	RR	15	CG	0.4	1.28	no	both	L-B
27	ch4	PA	15	CG	0.4	1.28	no	both	L-B
28	ch4	PR	15	CG	0.4	1.28	no	both	L-B
29	8	RA	15	CG	0.4	1.28	no	both	
30	8	RR	15	CG	0.4	1.28	no	both	
31	8	RA	15	CG	0.4	1.16	no	both	
32	8	RR	15	CG	0.4	1.16	no	both	
33	10	RA	12	CG	0.4	1.28	yes	both	
34	10	RR	12	CG	0.4	1.28	yes	both	
35	10	RA	12	CG	0.8	1.28	yes	both	
36	10	RR	12	CG	0.8	1.28	yes	both	
37	10	RA	12	CG	0.4	1.16	yes	both	
38	10	RR	12	CG	0.4	1.16	yes	both	
39	10	RA	12	CG	0.8	1.16	yes	both	
40	10	RR	12	CG	0.8	1.16	yes	both	

PLOT NO	REF TAB	RESP	RUD ANG	DR ANG	COEF C_h	COEF CDSW	THRUST MAP	SDWL- FORCES	REMARK
41	11	RA	12	CG	0.4	1.28	yes	one	
42	11	RR	12	CG	0.4	1.28	yes	one	
43	11	RA	12	CG	0.8	1.28	yes	one	
44	11	RR	12	CG	0.8	1.28	yes	one	
45	11	RA	12	CG	0.4	1.16	yes	one	
46	11	RR	12	CG	0.4	1.16	yes	one	
47	11	RA	12	CG	0.8	1.16	yes	one	
48	11	RR	12	CG	0.8	1.16	yes	one	
49	12	RA	15	CG	0.4	1.28	no	both	ZS-0.1
50	12	RR	15	CG	0.4	1.28	no	both	ZS-0.1
51	12	RA	15	CG	0.4	1.28	no	both	ZS-0.2
52	12	RR	15	CG	0.4	1.28	no	both	ZS-0.2
53	12	RA	15	CG	0.4	1.28	no	both	ZS-0.3
54	12	RR	15	CG	0.4	1.28	no	both	ZS-0.3
55	13	RA	12	CG	0.4	1.28	yes	both	ZS-0.1
56	13	RR	12	CG	0.4	1.28	yes	both	ZS-0.1
57	13	RA	12	CG	0.4	1.28	yes	both	ZS-0.2
58	13	RR	12	CG	0.4	1.28	yes	both	ZS-0.2
59	13	RA	12	CG	0.4	1.28	yes	both	ZS-0.3
60	13	RR	12	CG	0.4	1.28	yes	both	ZS-0.3
61	ch4	RA	12	CG	0.4	1.28	no	both	DF16
62	ch4	RR	12	CG	0.4	1.28	no	both	DF16
63	ch4	RA	12	CG	0.4	1.28	yes	both	DF16
64	ch4	RR	12	CG	0.4	1.28	yes	both	DF16
65	ch4	RA	12	CG	0.4	1.28	yes	both	DF16
66	ch4	RR	12	CG	0.4	1.28	yes	both	P*|P|
67	ch4	RA	12	CG	0.8	1.28	yes	one	DF16
68	ch4	RR	12	CG	0.8	1.28	yes	one	DF16
69	ch4	RA	12	CG	0.8	1.28	yes	one	DF16
70	ch4	RR	12	CG	0.8	1.28	yes	one	P*|P|
71	ch4	RA	12	CG	0.8	1.28	yes	one	DF16
72	ch4	RR	12	CG	0.8	1.28	yes	one	P*PI

PLOT NO	REF TAB	RESP	RUD ANG	DR ANG	COEF C_h	COEF CDSW	THRUST MAP	SDWL-FORCES	REMARK
73	ch4	RA	12	CG	0.4	1.28	no	both	DF16
74	ch4	RR	12	CG	0.4	1.28	no	both	L-B
75	ch4	RA	12	CG	0.4	1.28	yes	both	DF16
76	ch4	RR	12	CG	0.4	1.28	yes	both	L-B
77	ch4	RA	12	CG	0.4	1.28	yes	both	DF16
78	ch4	RR	12	CG	0.4	1.28	yes	both	P*PI
79	ch4	RA	12	CG	0.8	1.28	yes	one	new
80	ch4	RR	12	CG	0.8	1.28	yes	one	Rud



PLØT IS RØLL ANGLE VERSUS TIME

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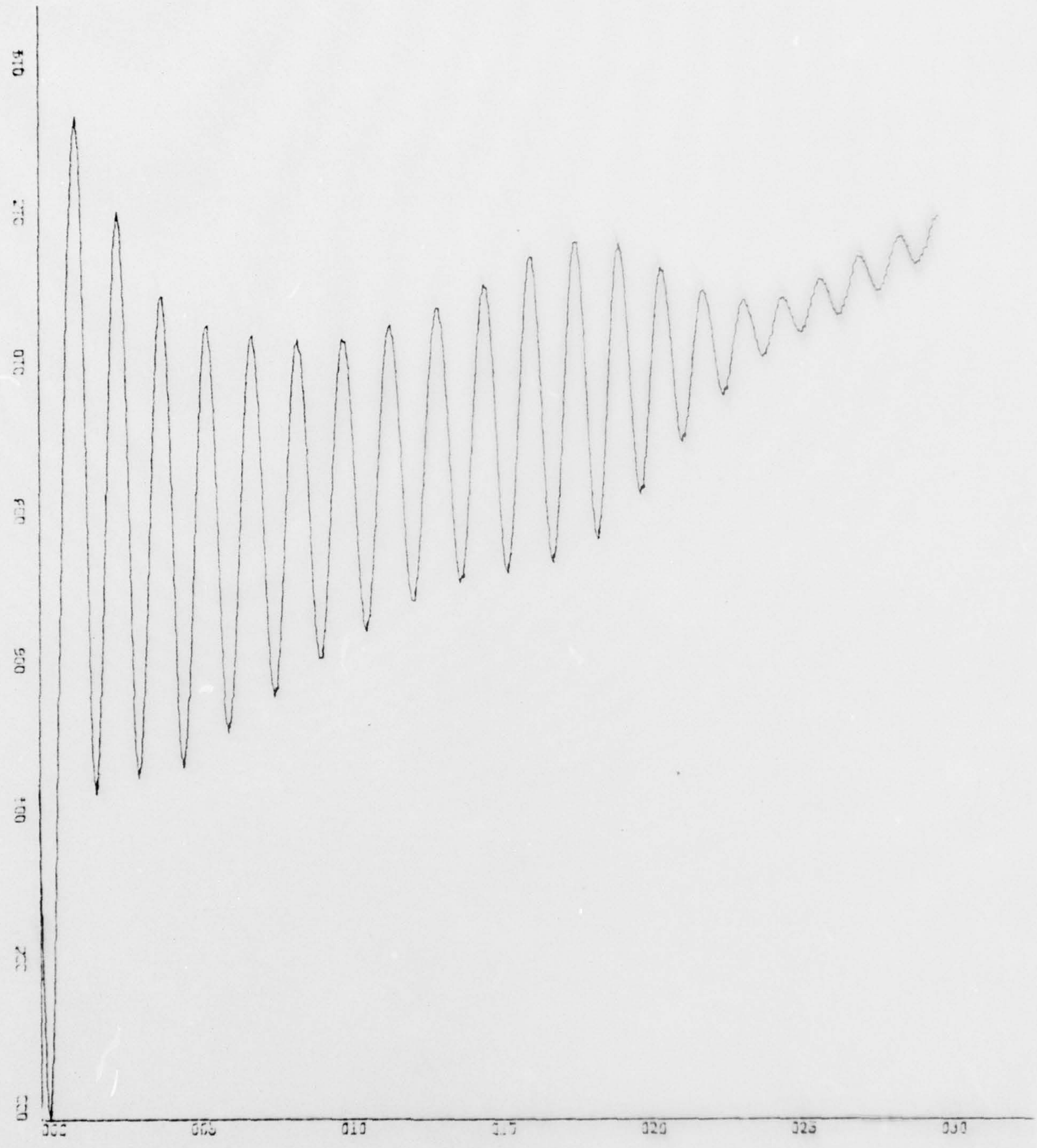
Y-SCALE=1.00E+00 UNITS INCH.

PLOT 1

for applied parameters see first page of this appendix



PLOT IS PITCH ANGLE VERSUS TIME

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~~Y-SCALE=2.00E-01 UNITS INCH.~~

PLOT 2

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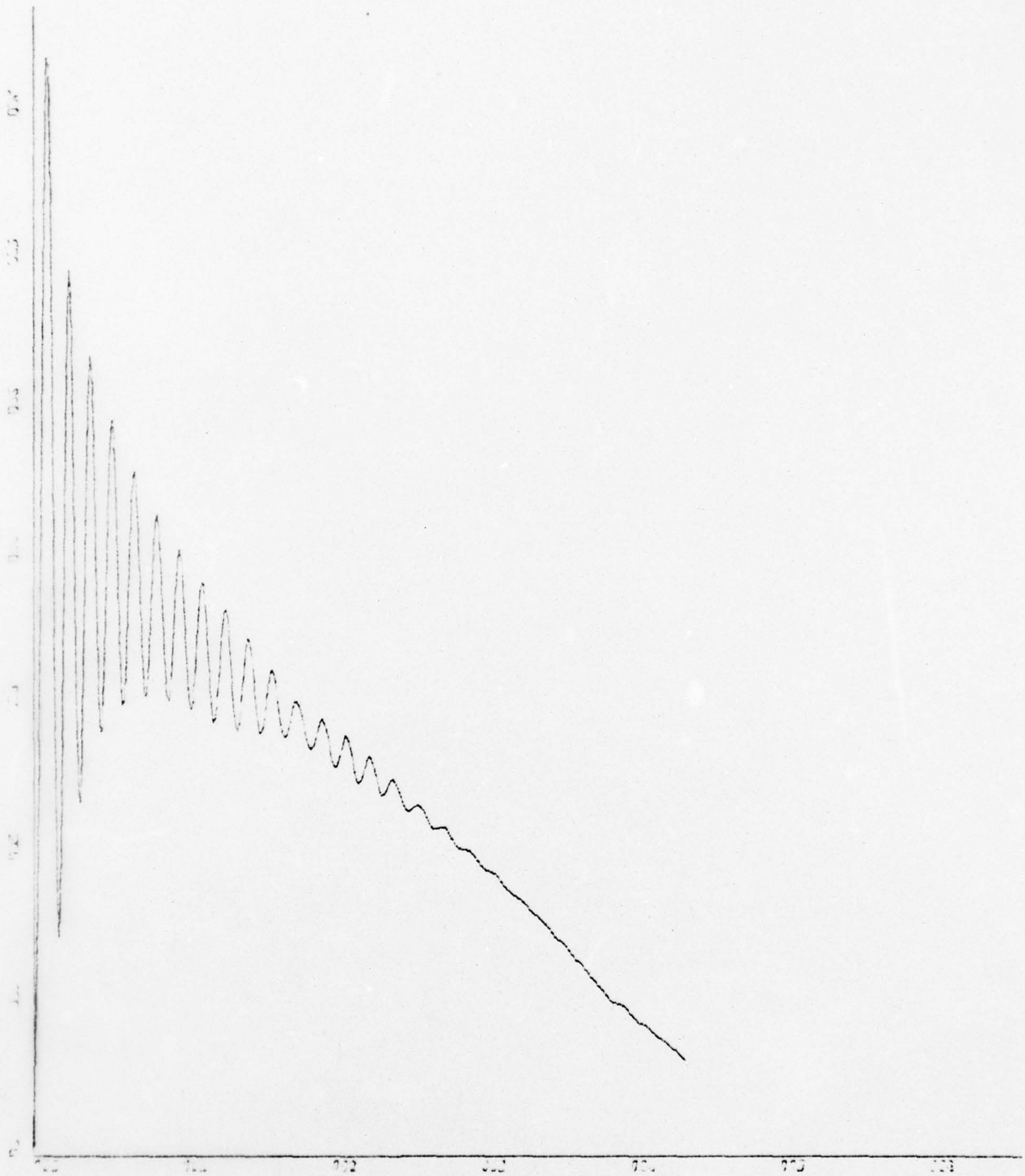

PLOT IS ROLL ANGLE VERSUS TIME

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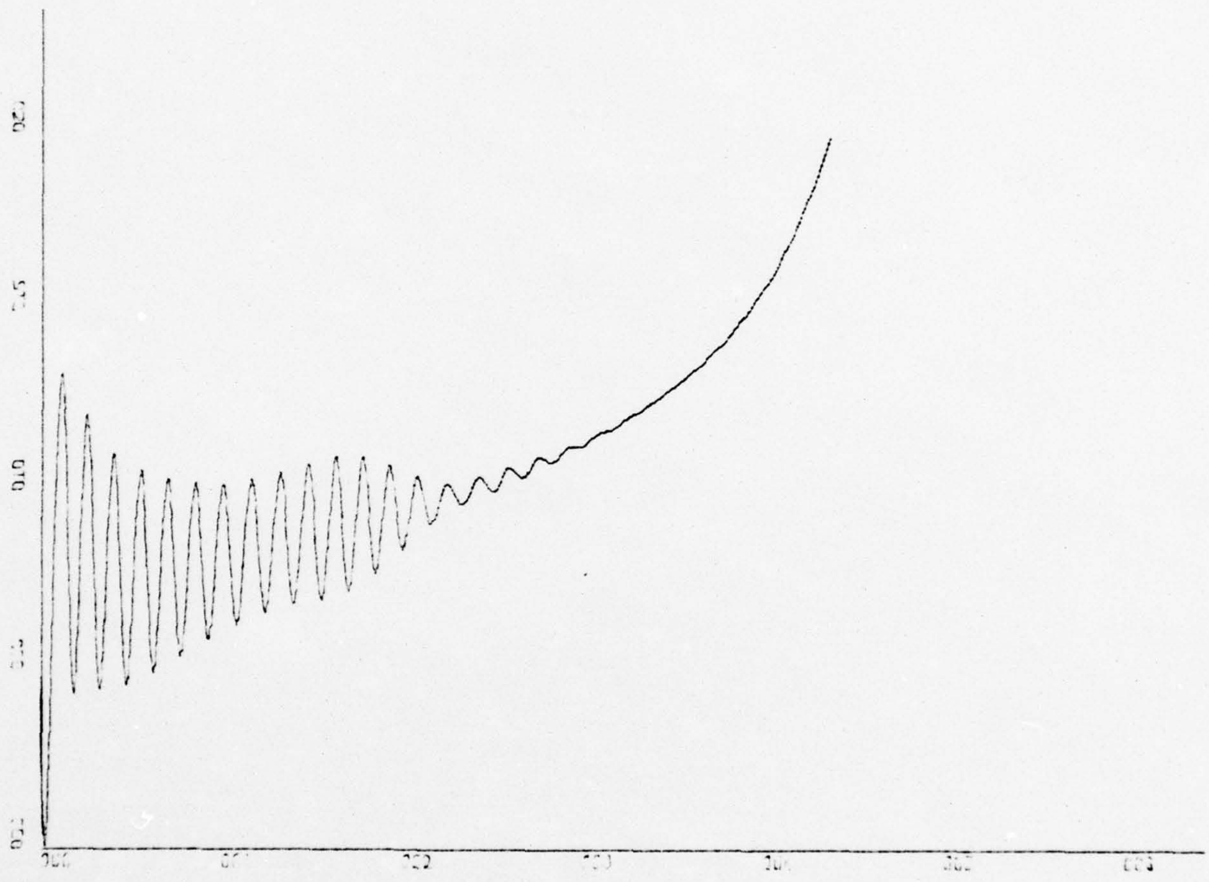
Y-SCALE=1.00E+00 UNITS INCH.

PLOT 3

for applied parameters see first page of this appendix



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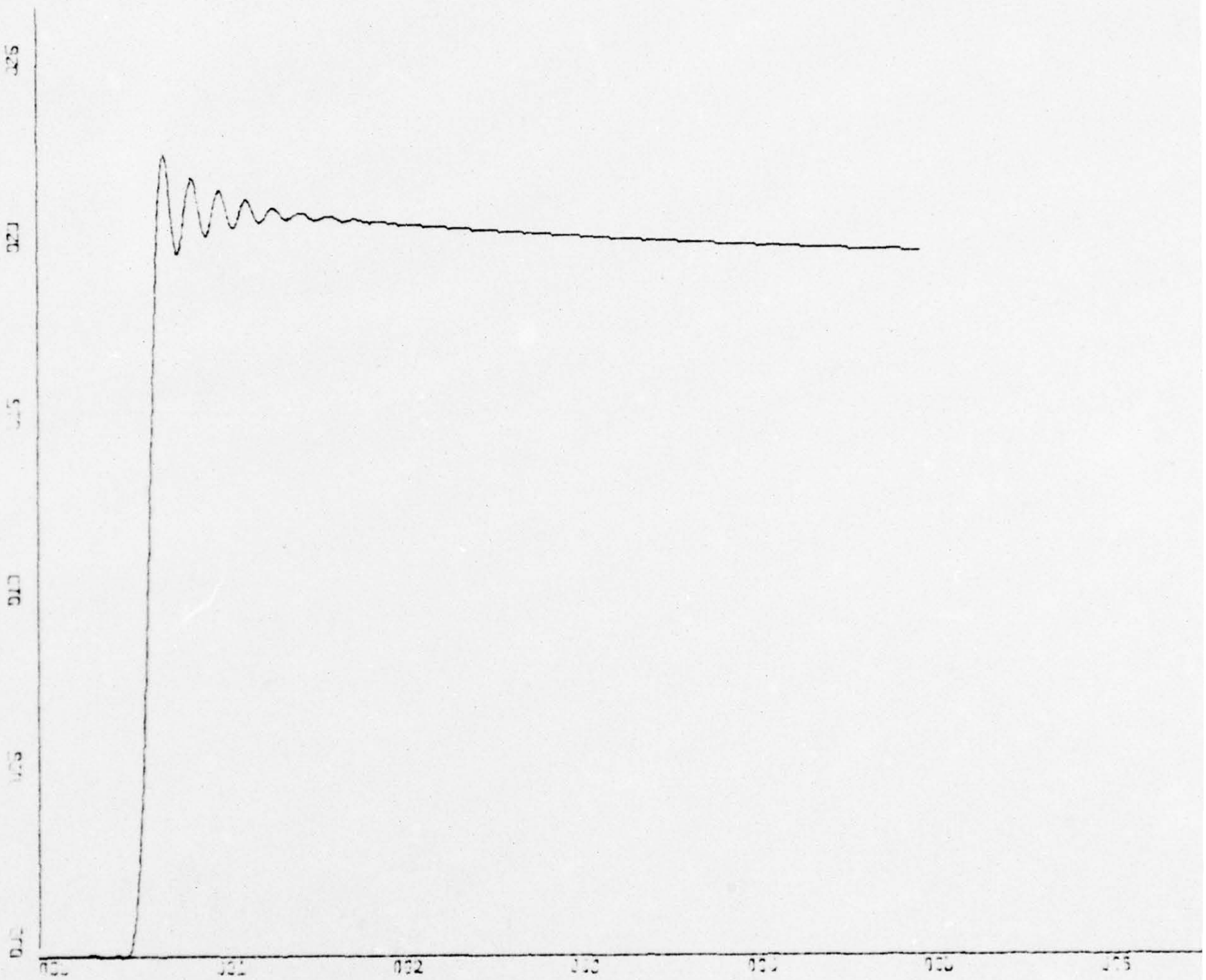
AGROB3 . TURN 20 KN. NO RD
PLOT IS PITCH ANGLE VERSUS TIME

PLOT 4

for applied parameters see first page of this appendix



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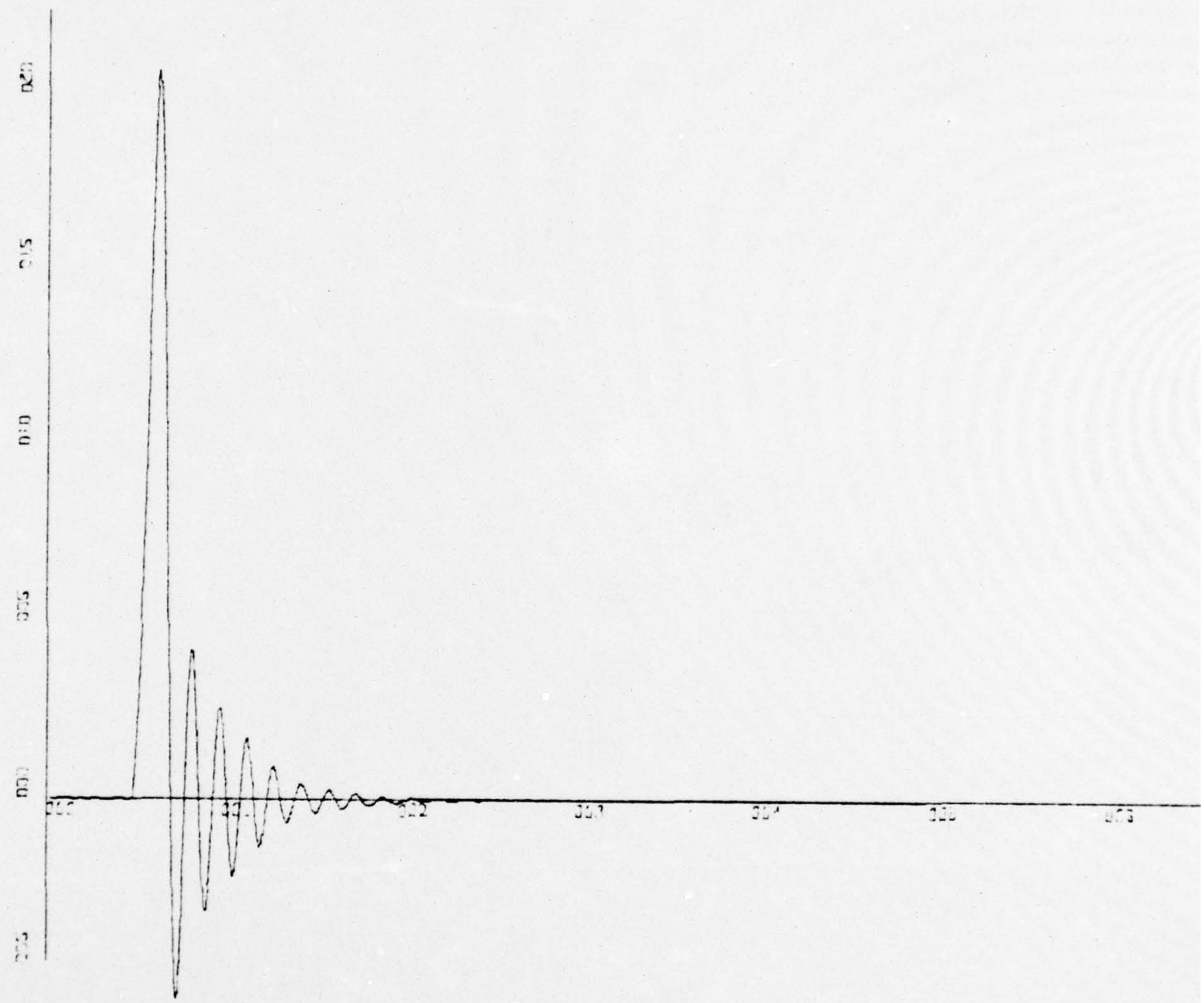
Y-SCALE=5.00E-01 UNITS INCH.
RGROD2 , TURN 20 KN , RUDM=15
PLØT IS ROLL ANGLE VERSUS TIME

PLOT 5

for applied parameters see first page of this appendix



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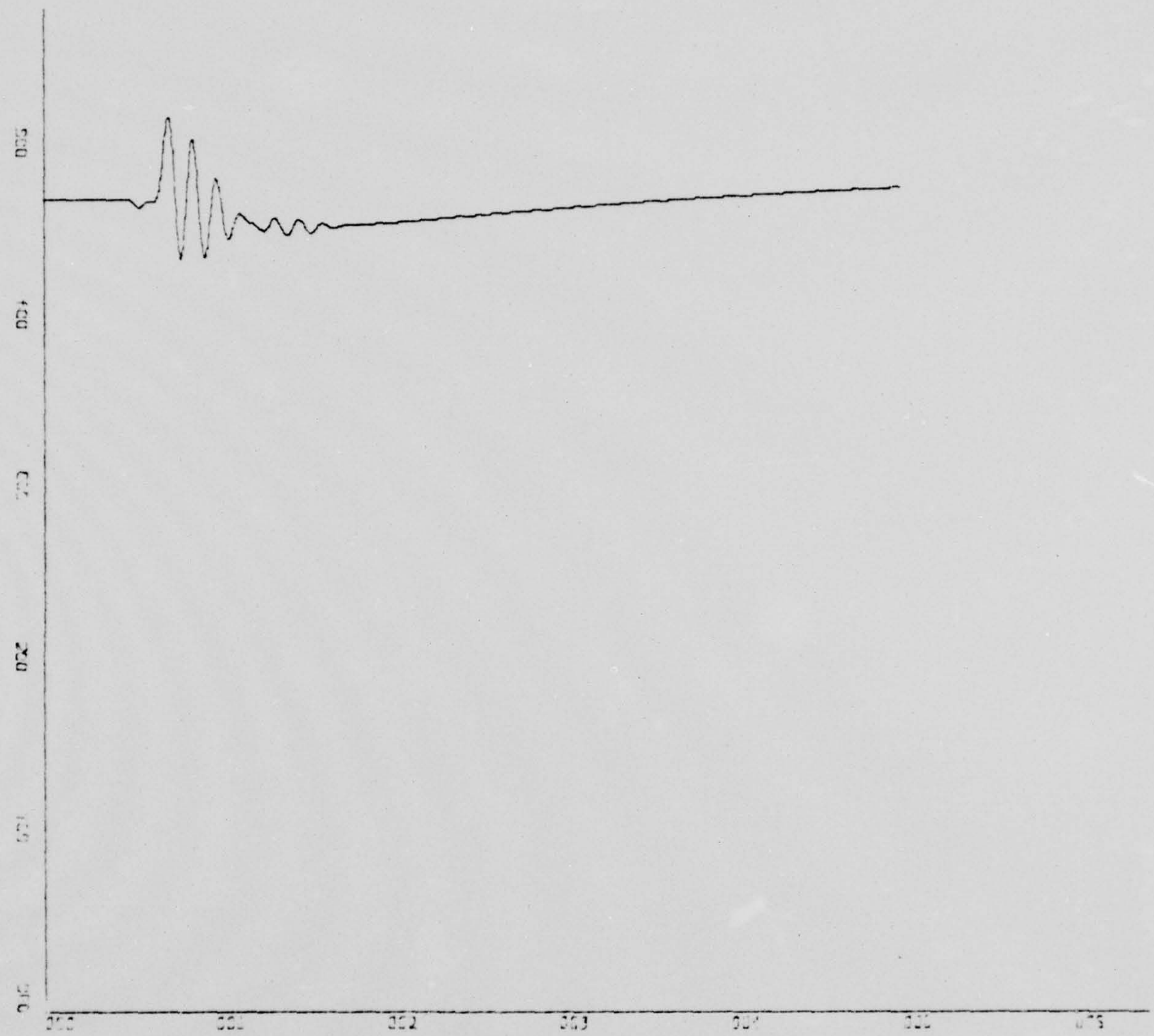
Y-SCALE=5.00E-01 UNITS INCH.
RGROD2 . TURN 20 KN . RUDM=15
PLOT IS ROLL RATE VERSUS TIME

PLOT 6

for applied parameters see first page of this appendix



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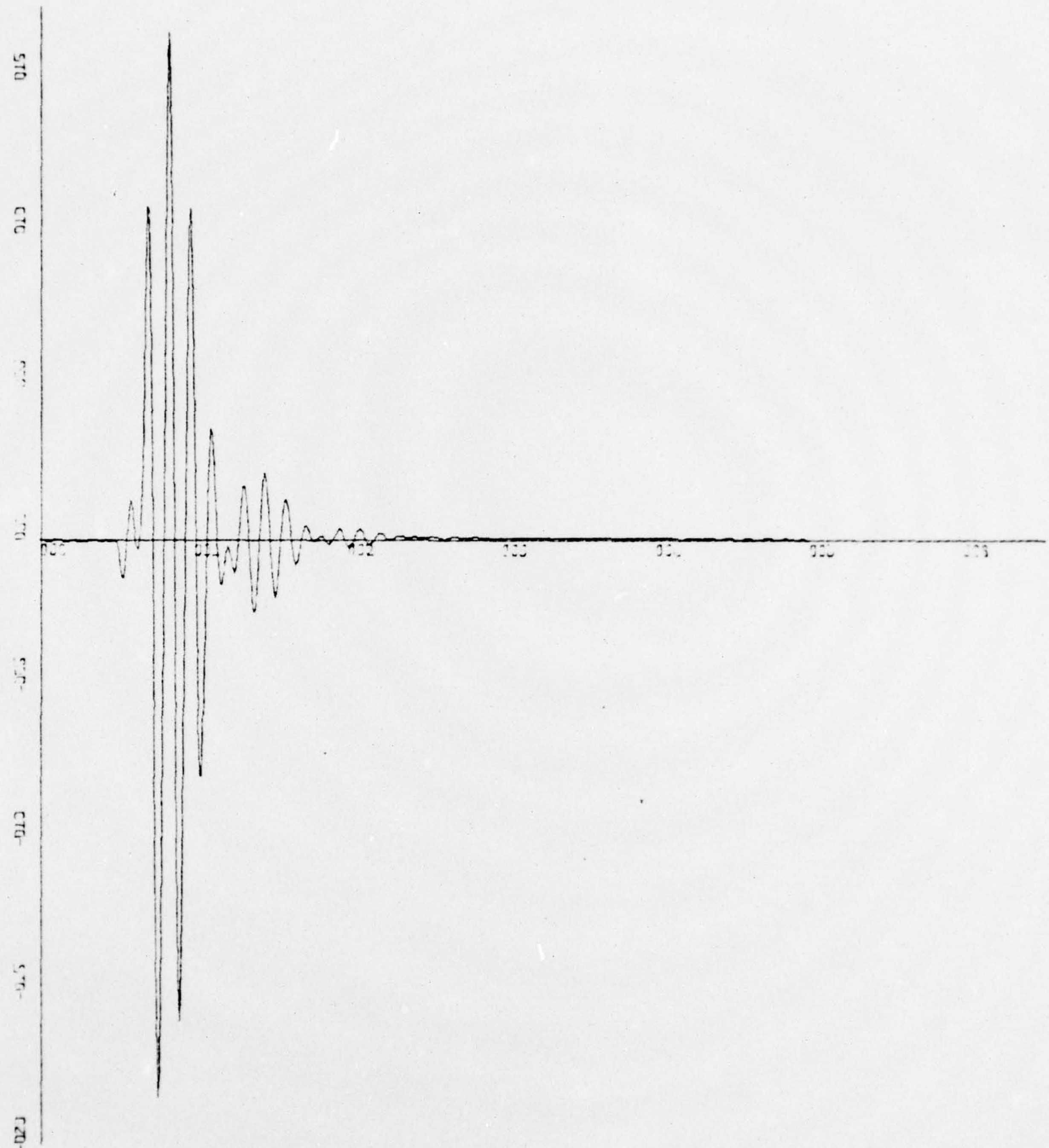
Y-SCALE 1.00E-01 UNITS INCH.
RGROD2 , TURN 20 KN , RUDM=15
PLOT IS PITCH ANGLE VERSUS TIME

PLOT 7

for applied parameters see first page of this appendix



PLØT IS PITCH RATE VERSUS TIME

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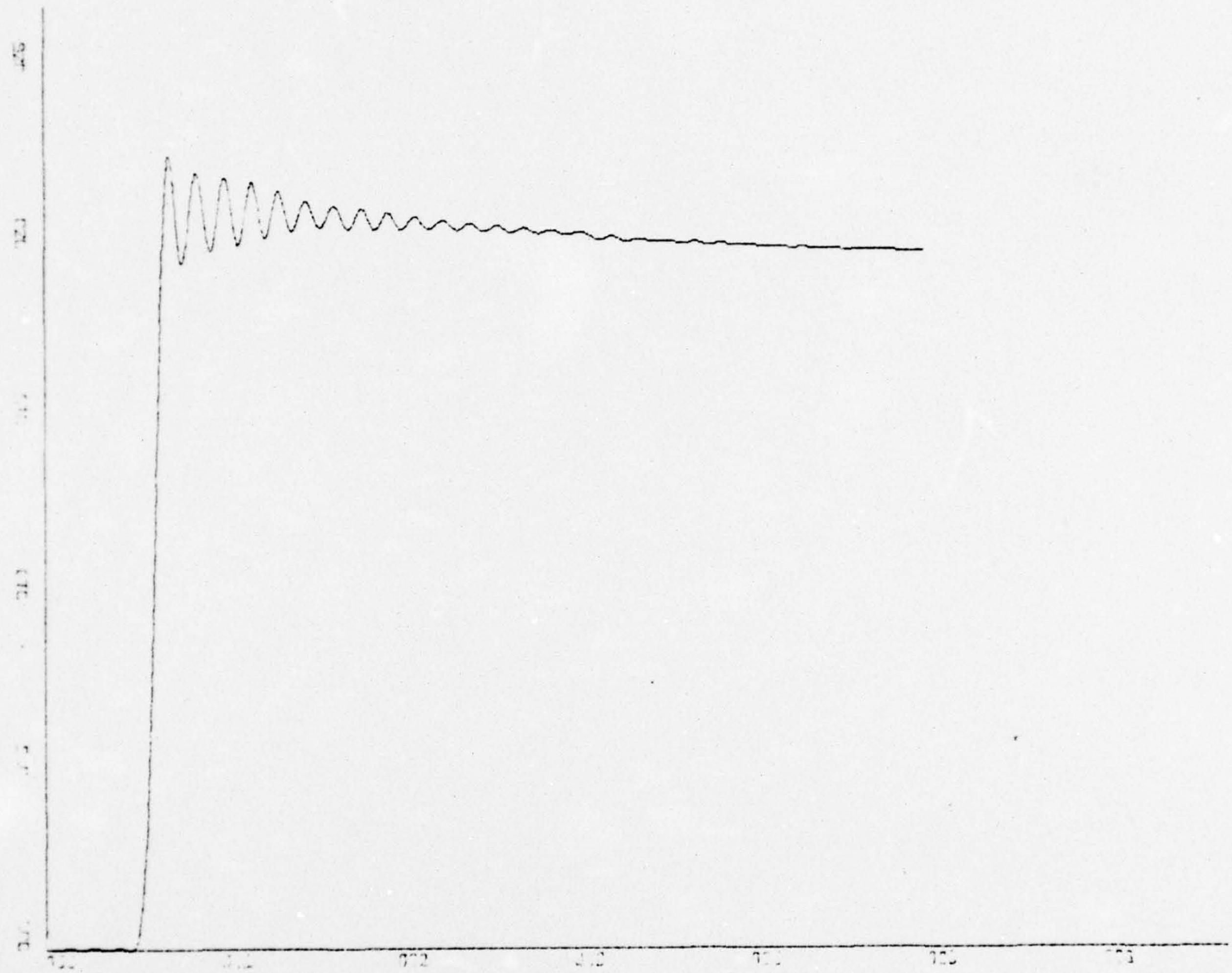
Y-SCALE=5.00E-02 UNITS INCH.

PLOT 8

for applied parameters see first page of this appendix



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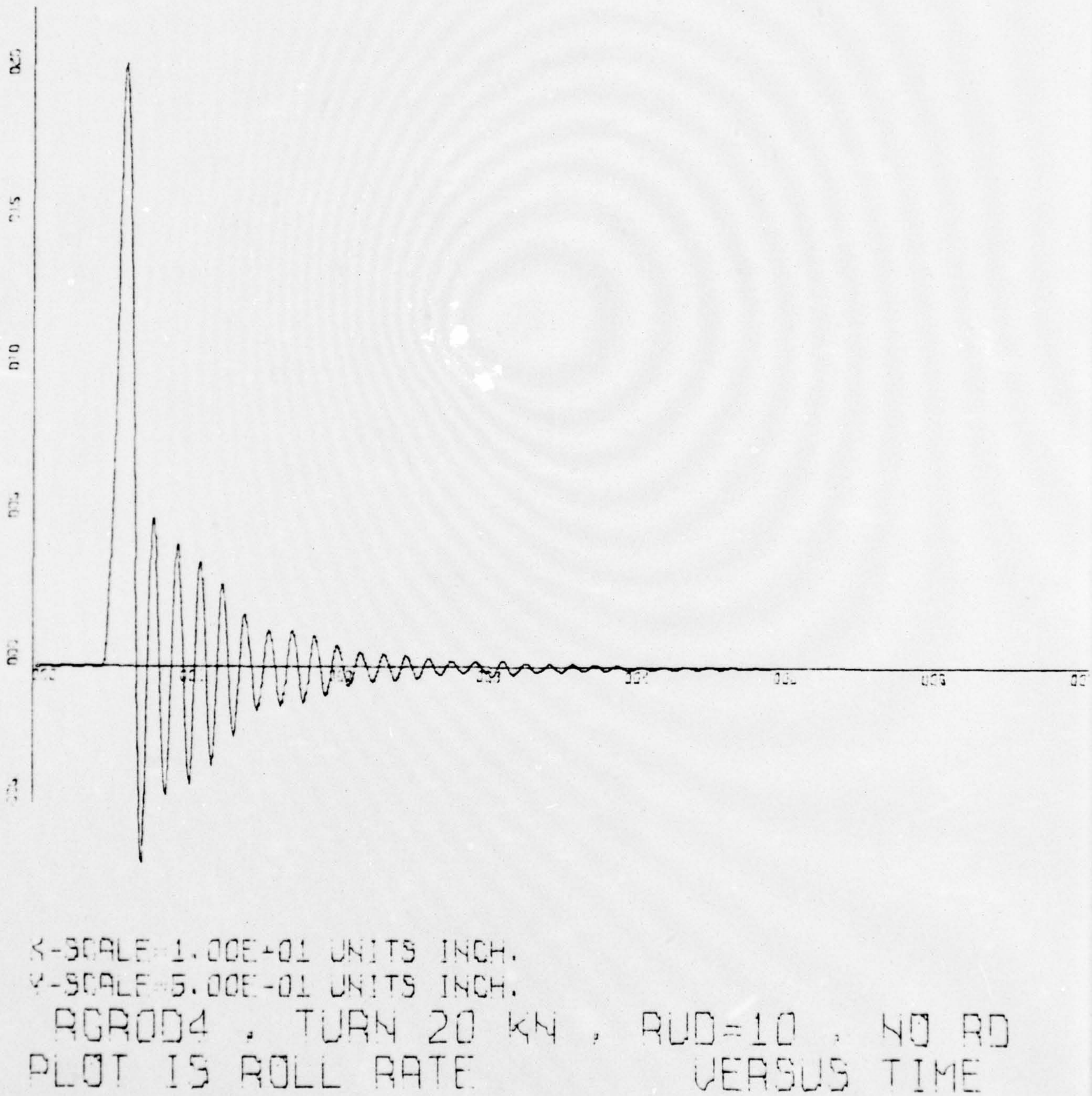
Y-SCALE=5.00E-01 UNITS INCH.
AGR004 , TURN 20 KN , RUD=10 , NO RD
PLOT IS ROLL ANGLE VERSUS TIME

PLOT 9

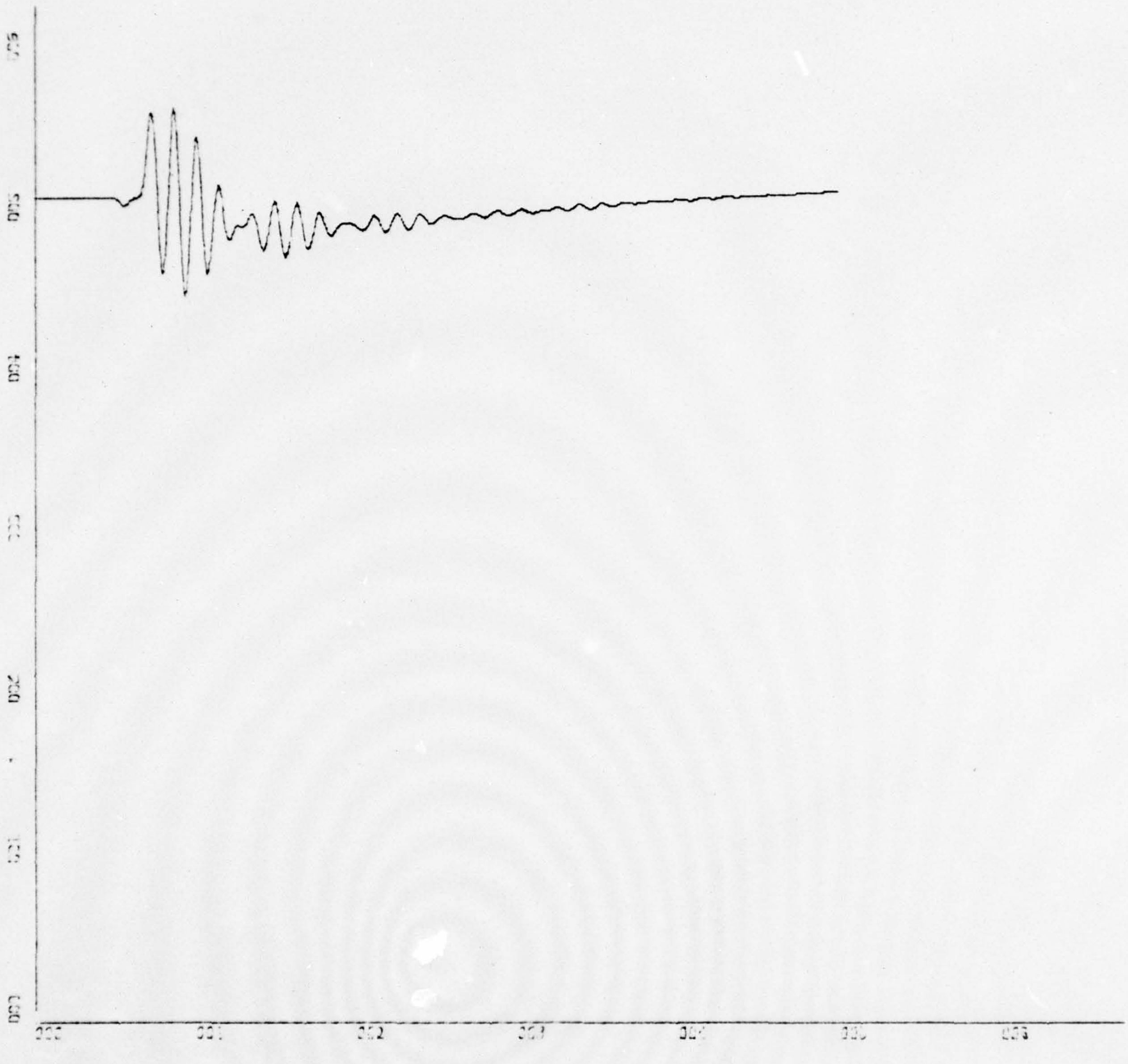
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGROD4 , TURN 20 KN , RUD=10 , NO RD
PLOT IS ROLL RATE VERSUS TIME

PLOT 10

for applied parameters see first page of this appendix

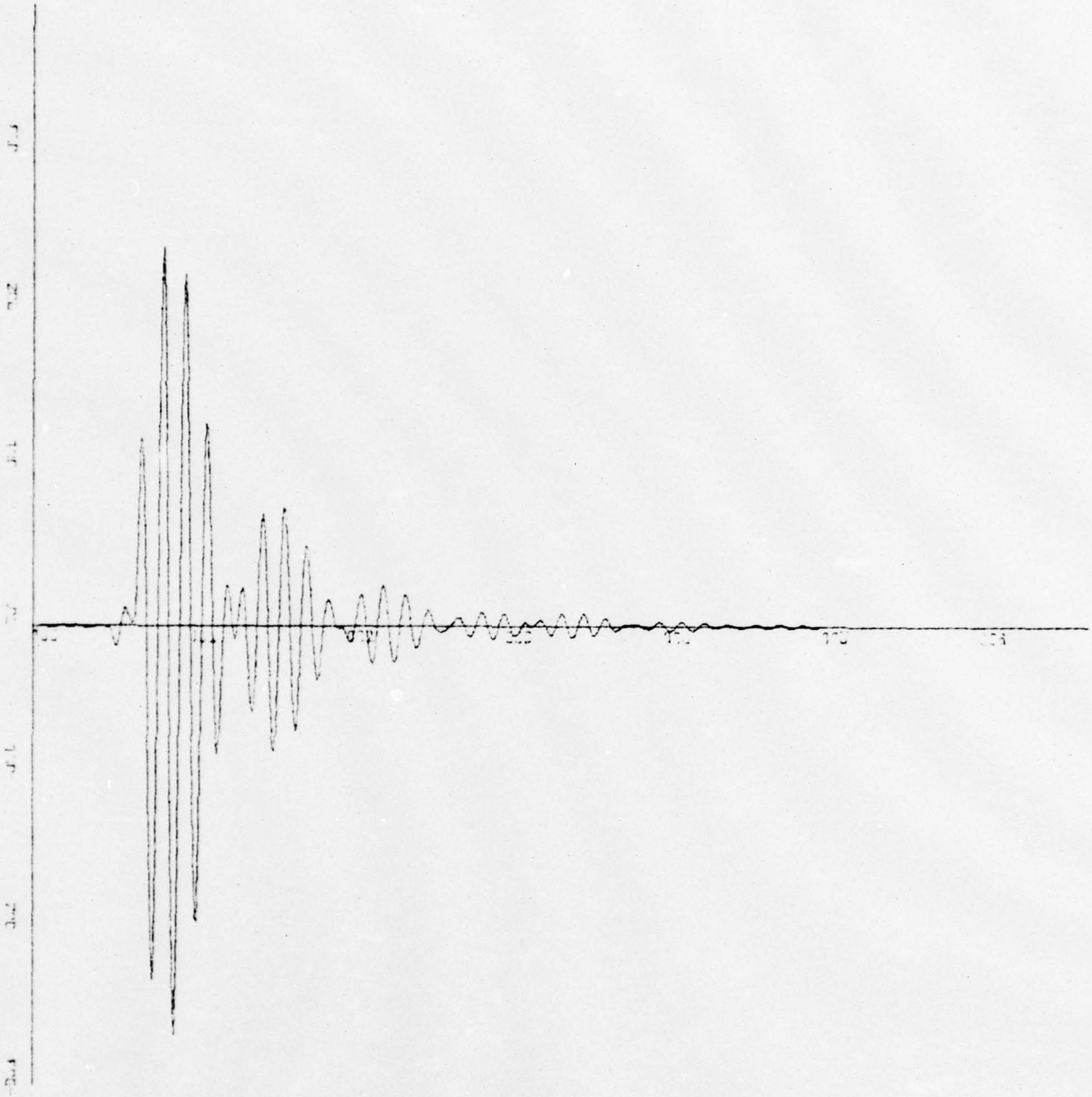


X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=1.00E-01 UNITS INCH.

RGR004 , TURN 20 KN , RUD=10 , NO RD
PLOT IS PITCH ANGLE VERSUS TIME

PLOT 11

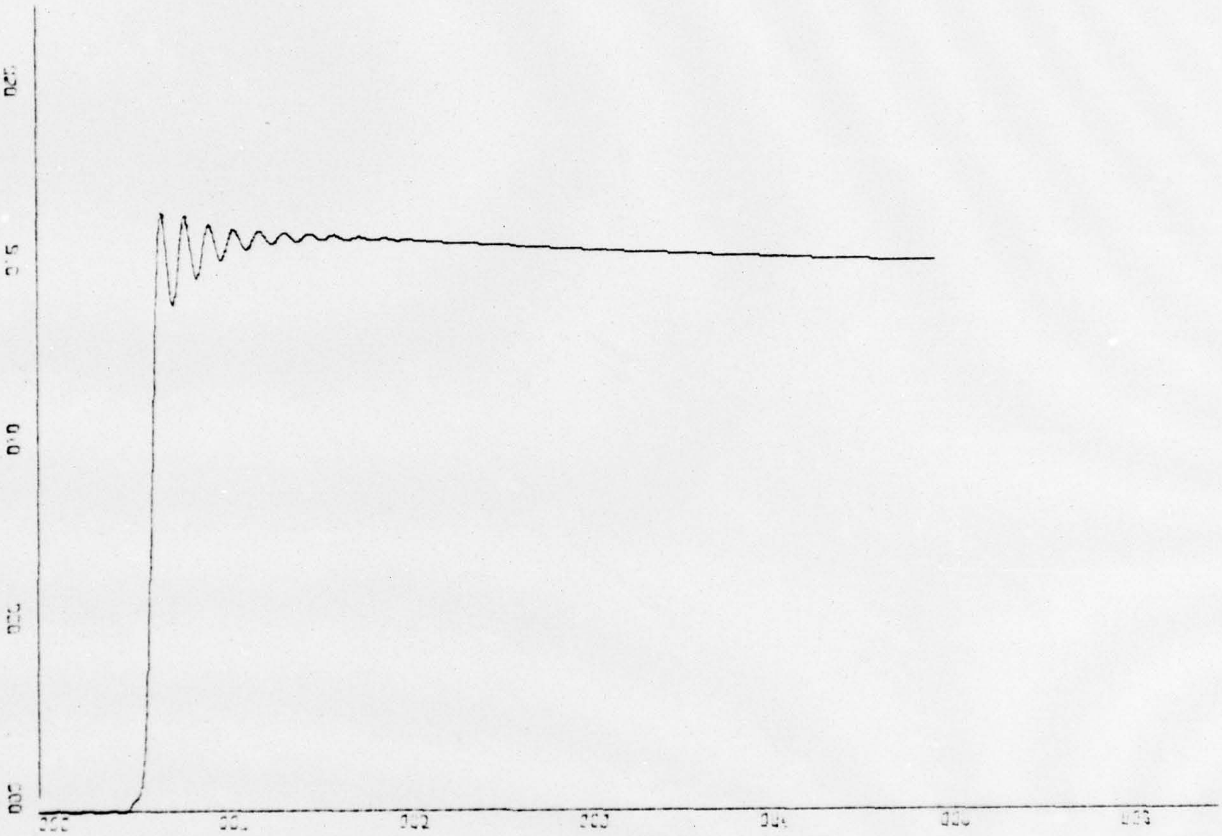
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=1.00E-01 UNITS INCH.
RGR004 , TURN 20 KN , RUD=10 , NO RD
PLOT IS PITCH RATE VERSUS TIME

PLOT 12

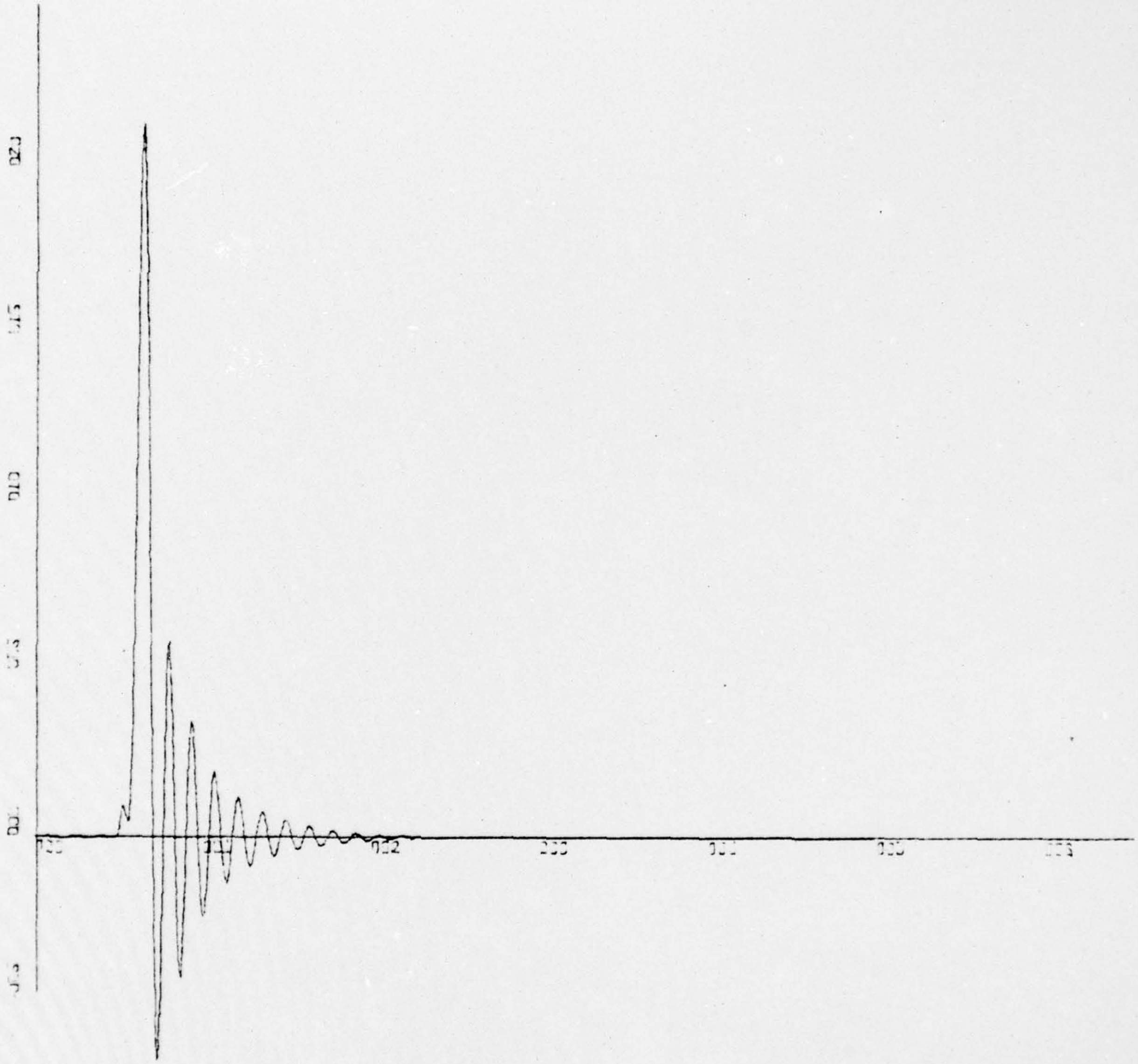
for applied parameters see first page of this appendix



K-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 5.00E-01 UNITS INCH.
RGRODS , TURN 20 KN , RUDM=15
PLOT IS ROLL ANGLE VERSUS TIME

PLOT 13

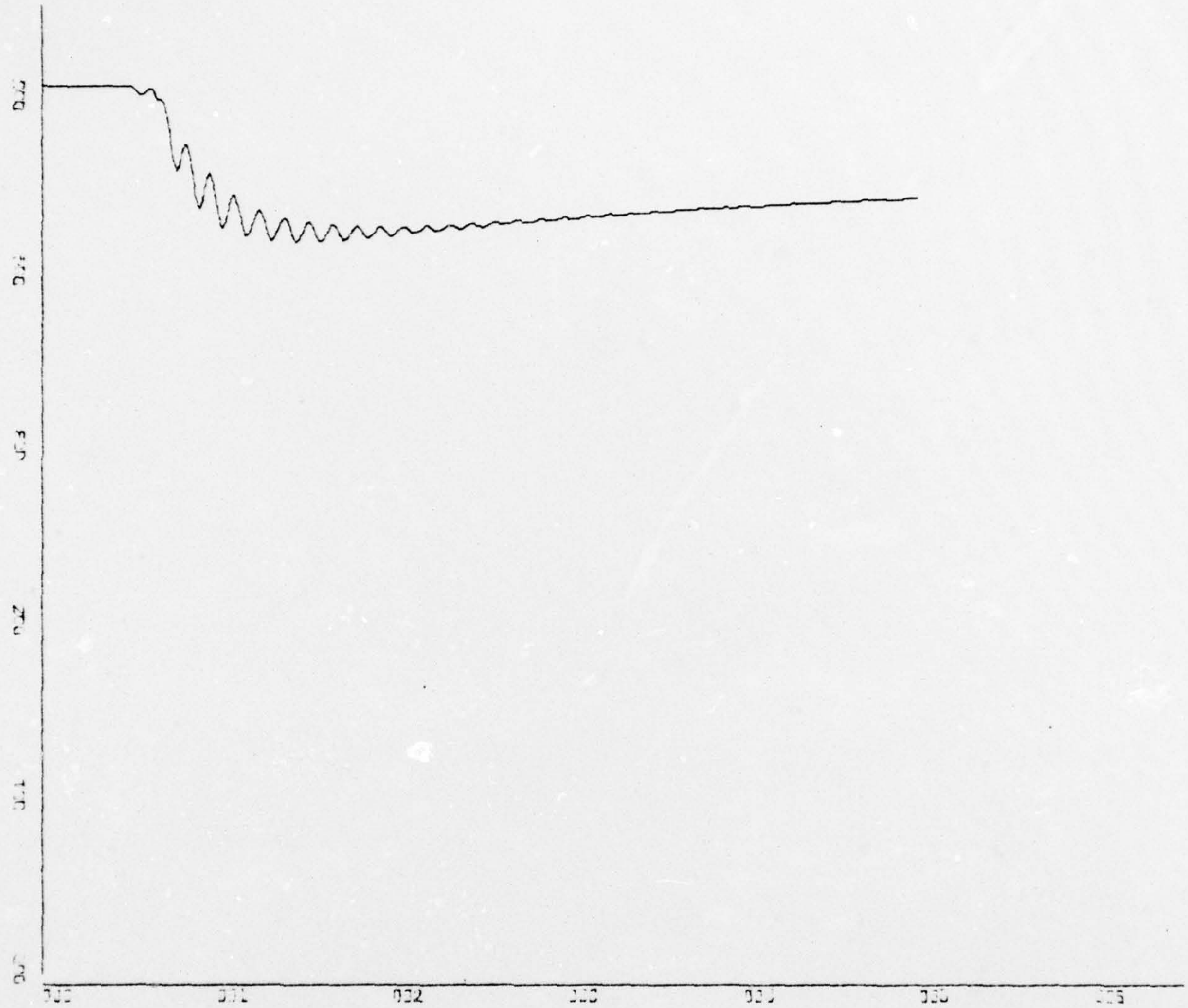
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGRODS , TURN 20 KN , RUDM=15
PLOT IS ROLL RATE VERSUS TIME

PLOT 14

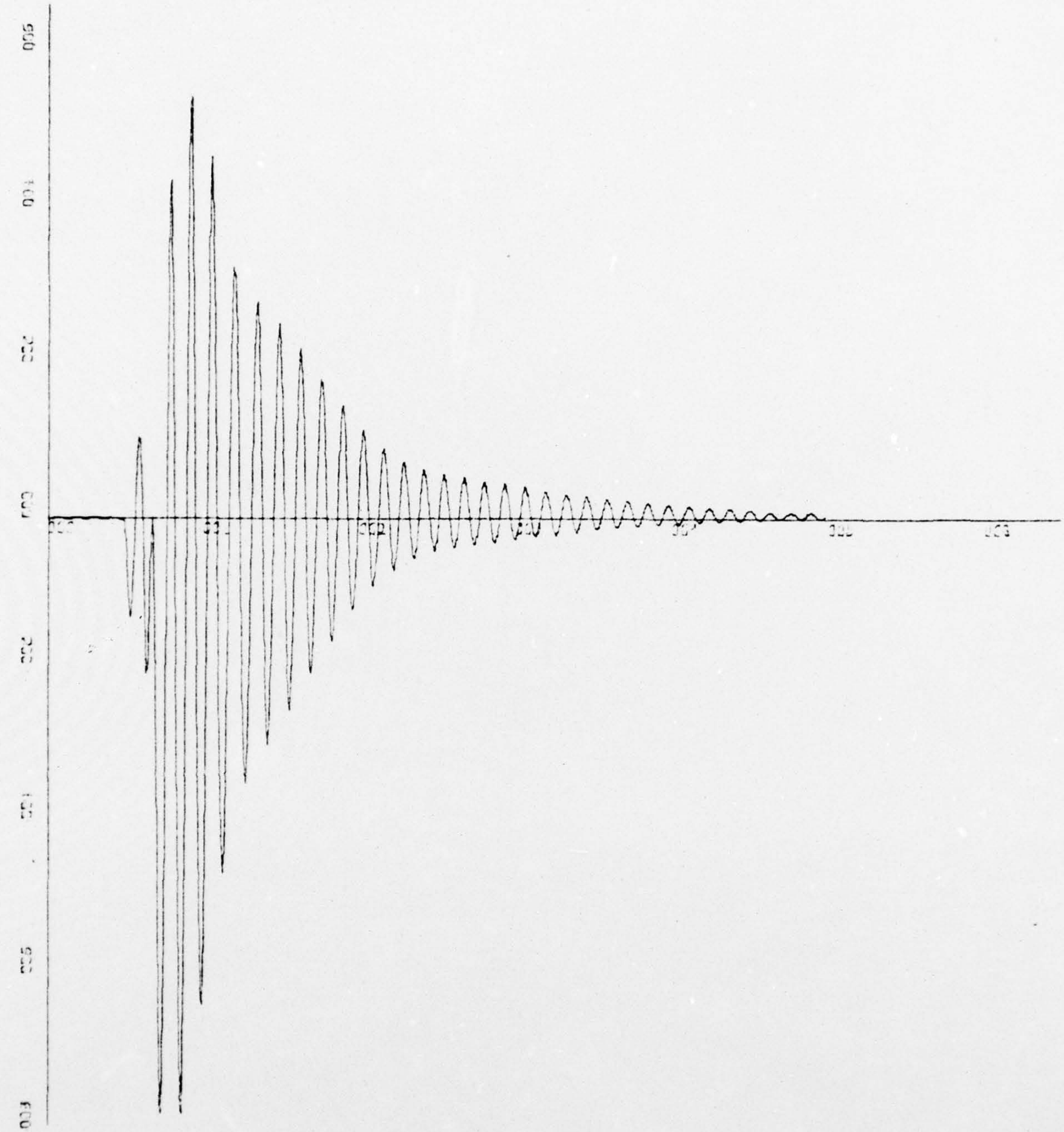
for applied parameters see first page of this appendix



K-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=1.00E-01 UNITS INCH.
RGROD5 , TURN 20 KN , RUDM=15
PLØT IS PITCH ANGLE VERSUS TIME

PLOT 15

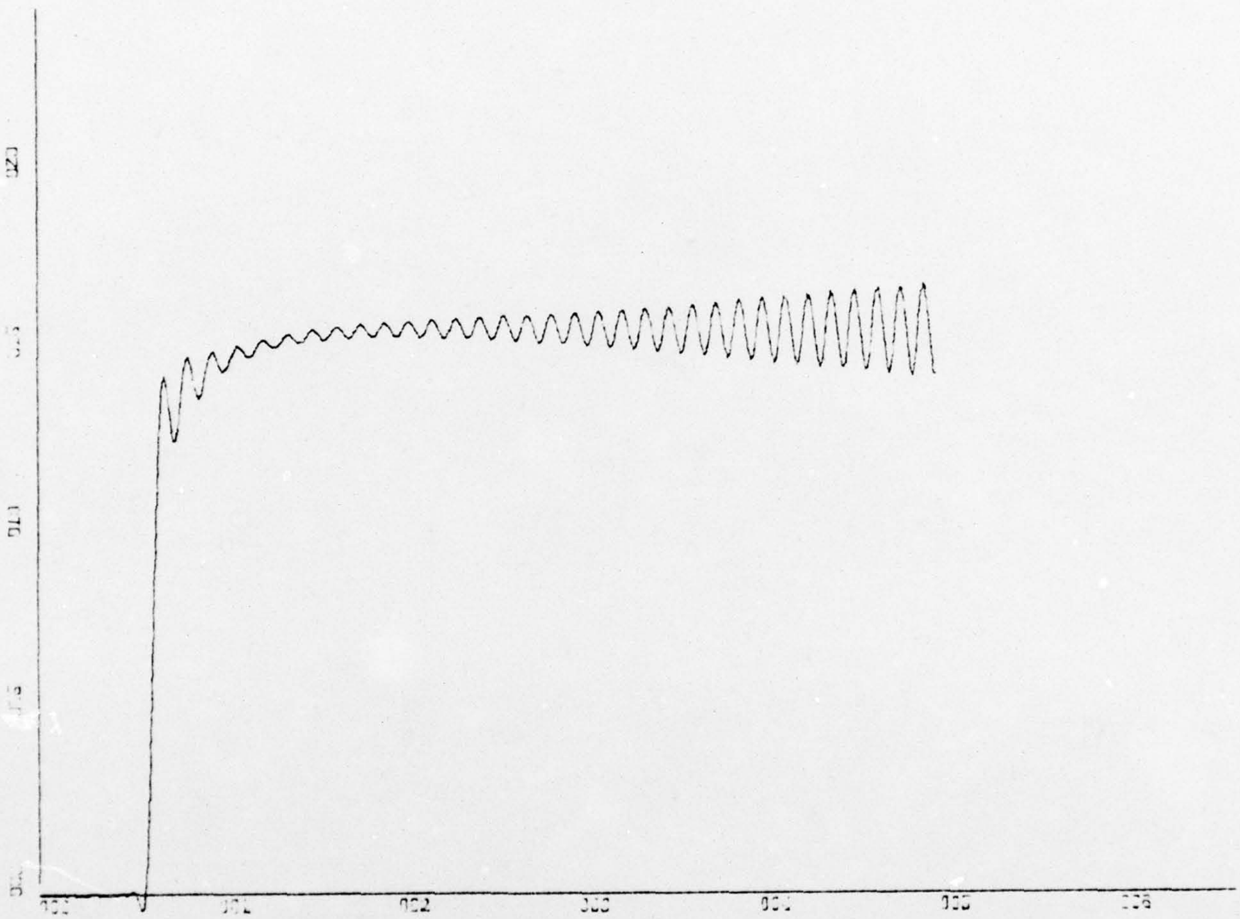
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-02 UNITS INCH.
AGRODS . TURN 20 KN . RUDM=15
PLOT IS PITCH RATE VERSUS TIME

PLOT 16

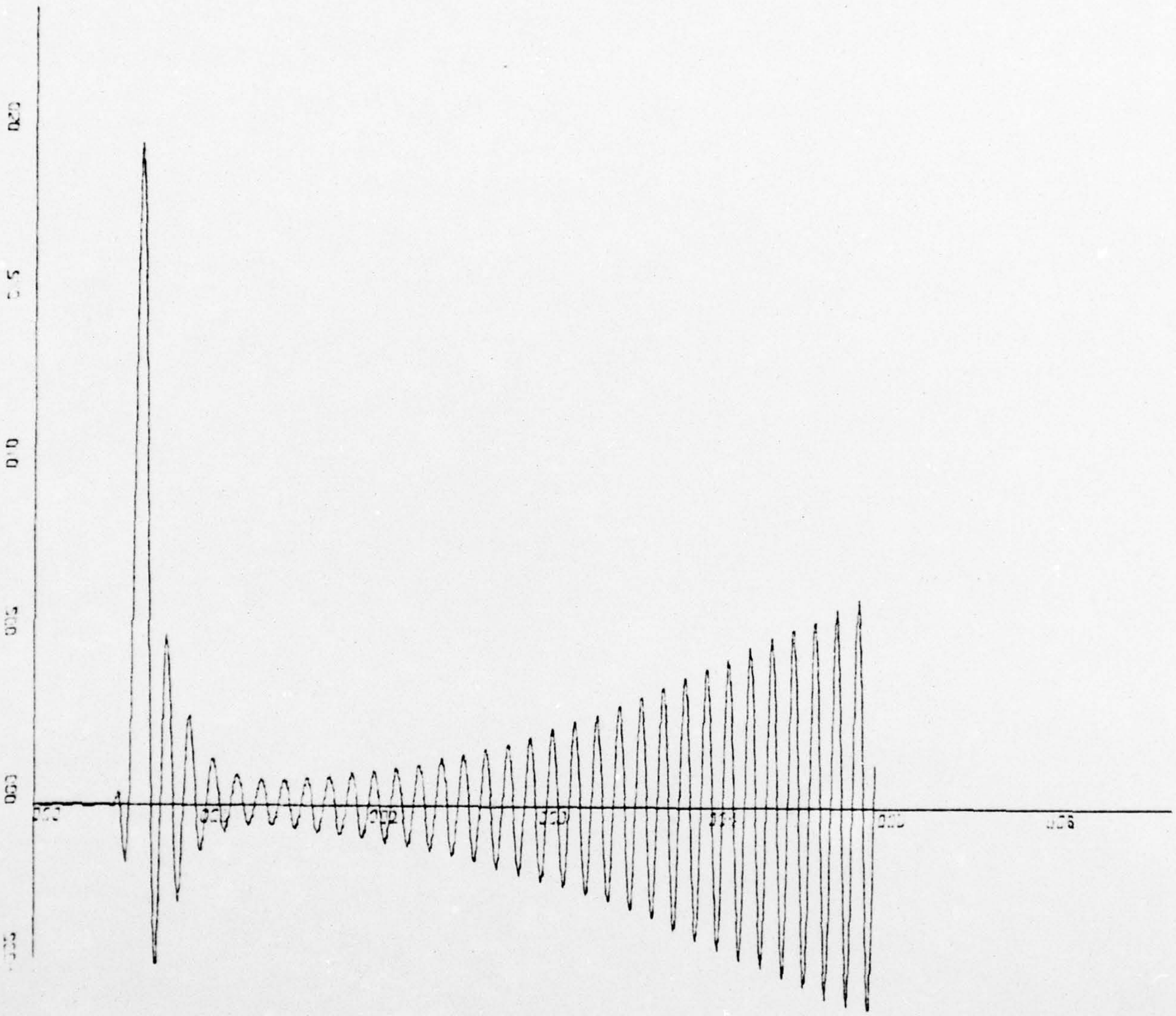
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGROE5 , TURN 20 KN , RUD=10 , NØ RD
PLØT IS RØLL ANGLE VERSUS TIME

PLOT 17

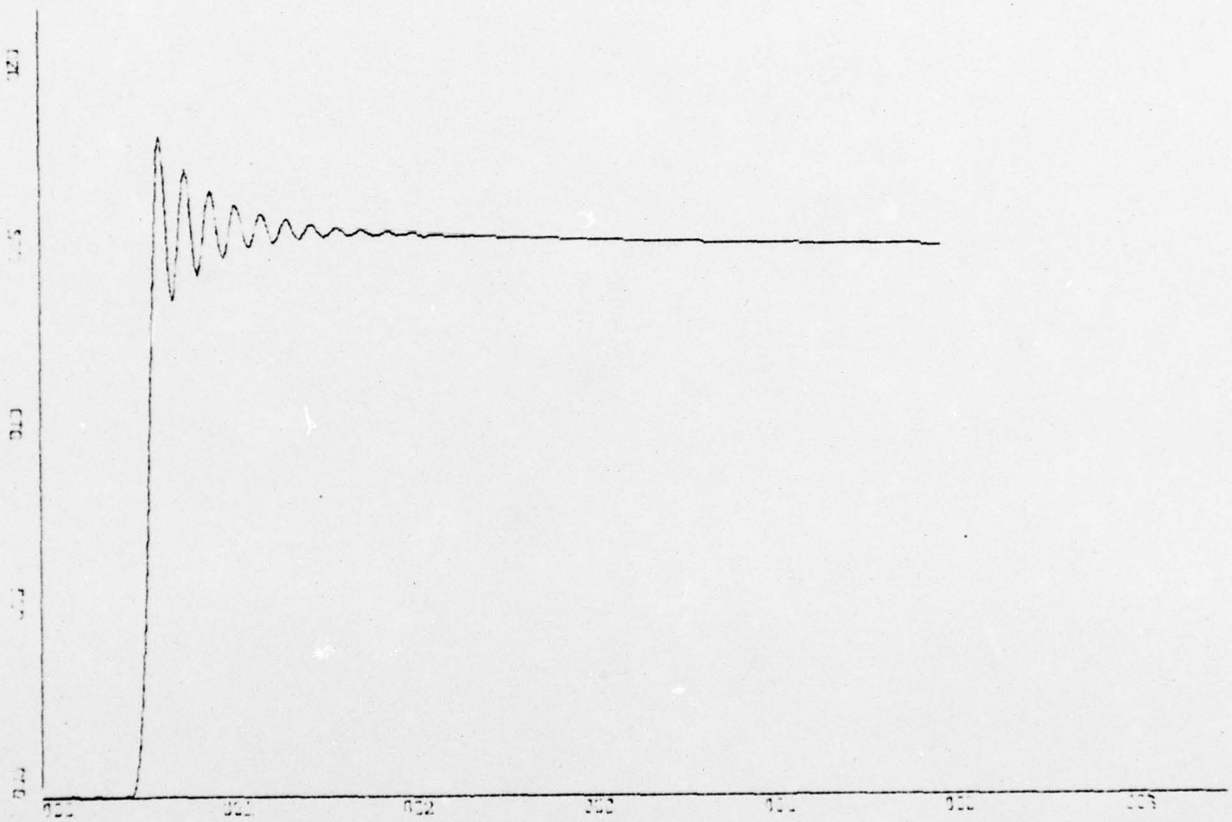
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGROE5 , TURN 20 KN , RUD=10 , NO RD
PLOT IS ROLL RATE VERSUS TIME

PLOT 18

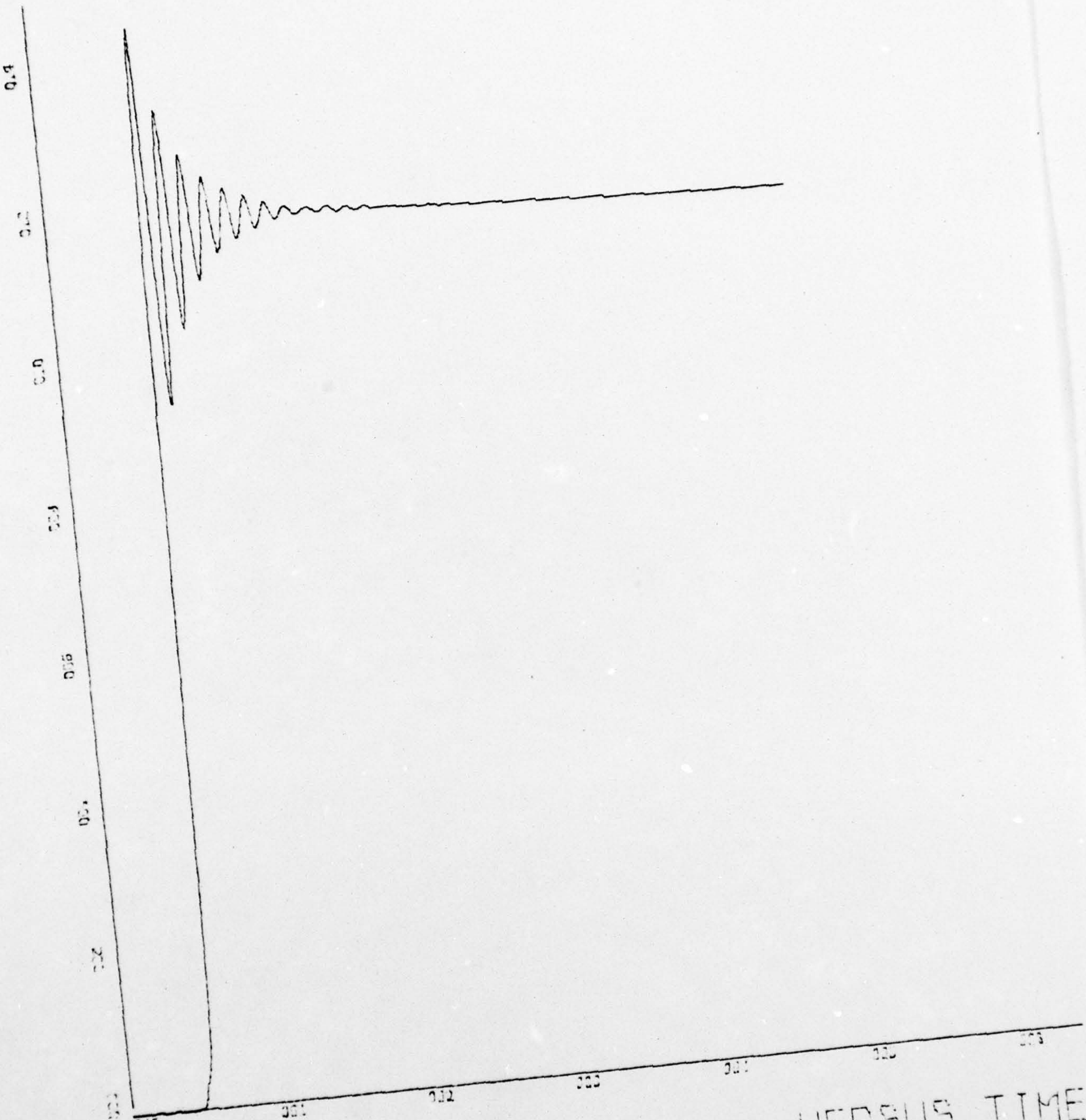
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGRT61 , TURN 20 KN.
PLOT IS ROLL ANGLE VERSUS TIME

PLOT 19

for applied parameters see first page of this appendix

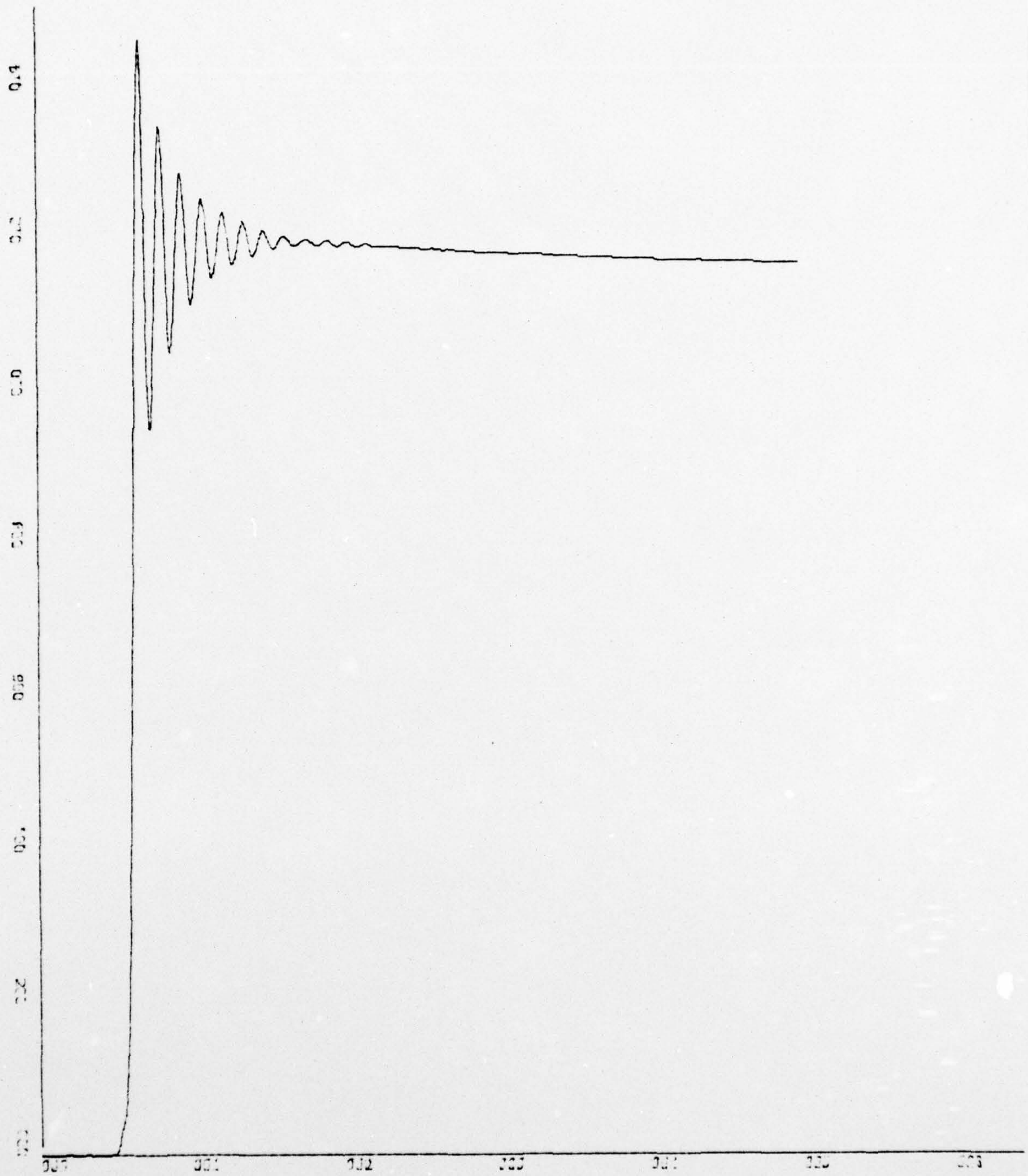


PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.

PLOT 21

for applied parameters see first page of this appendix

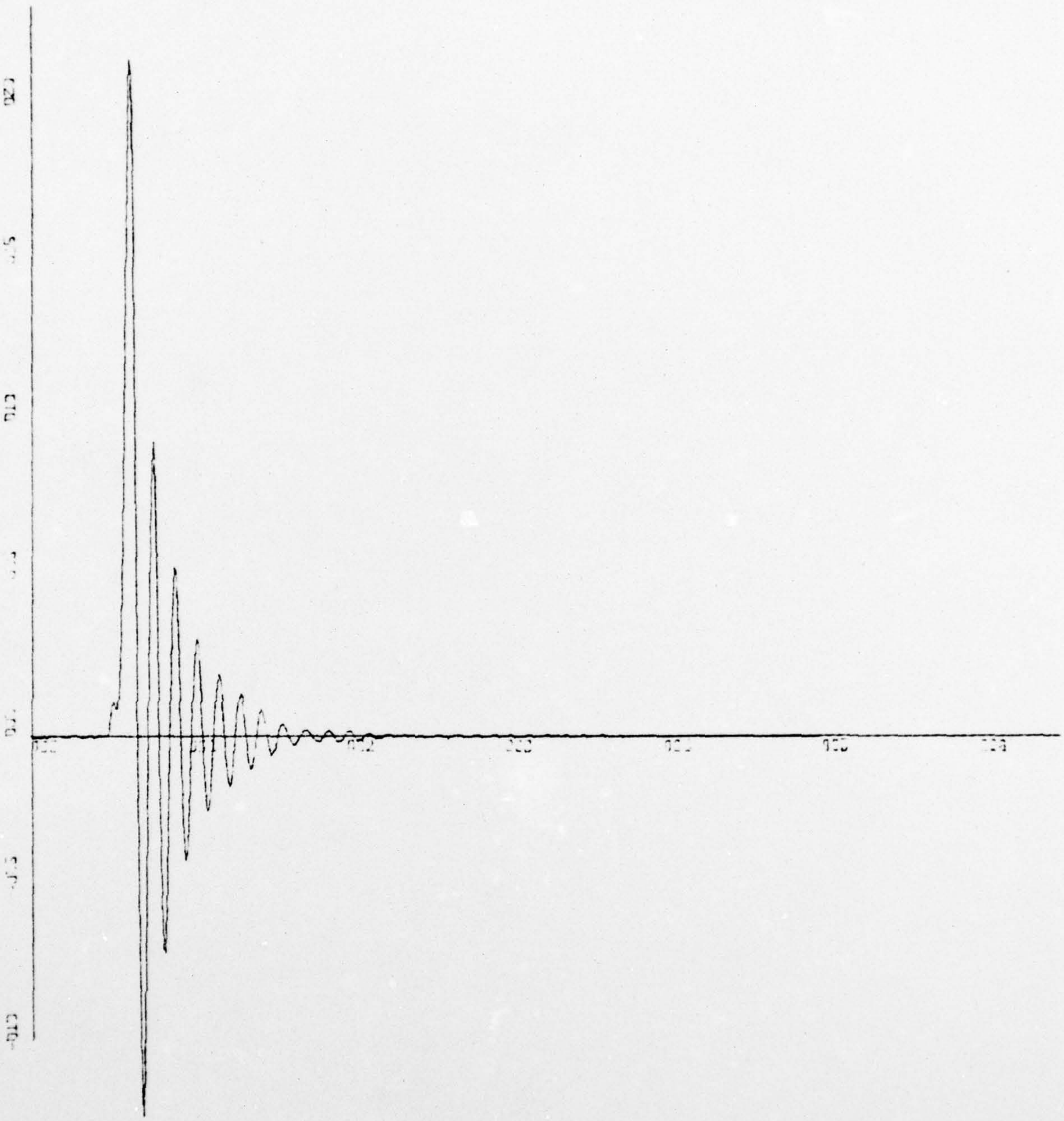


PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.

PLOT 21

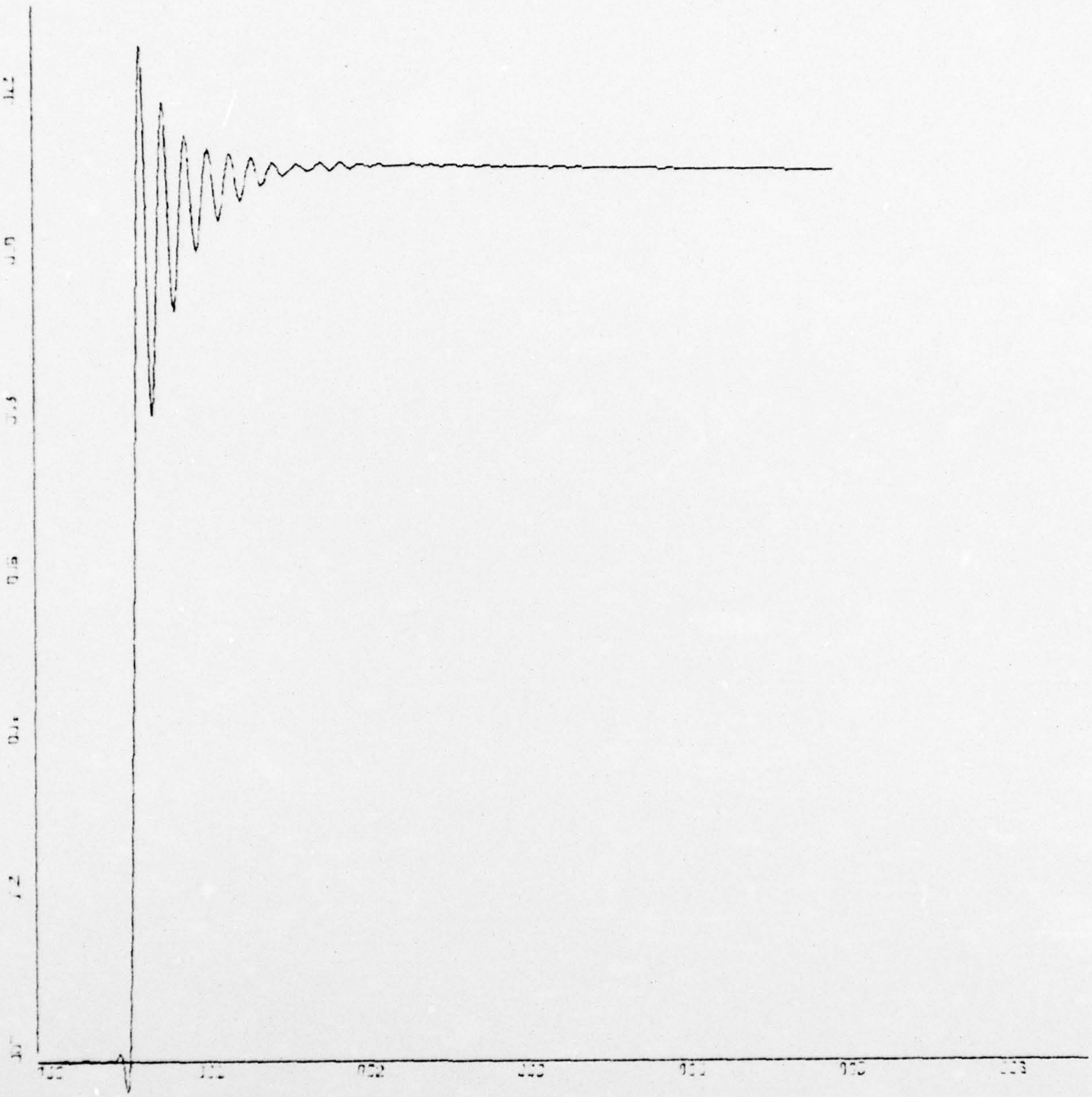
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
AGAT62 , TURN 20 KN.
PLØT IS RØLL RATE VERSUS TIME

PLOT 22

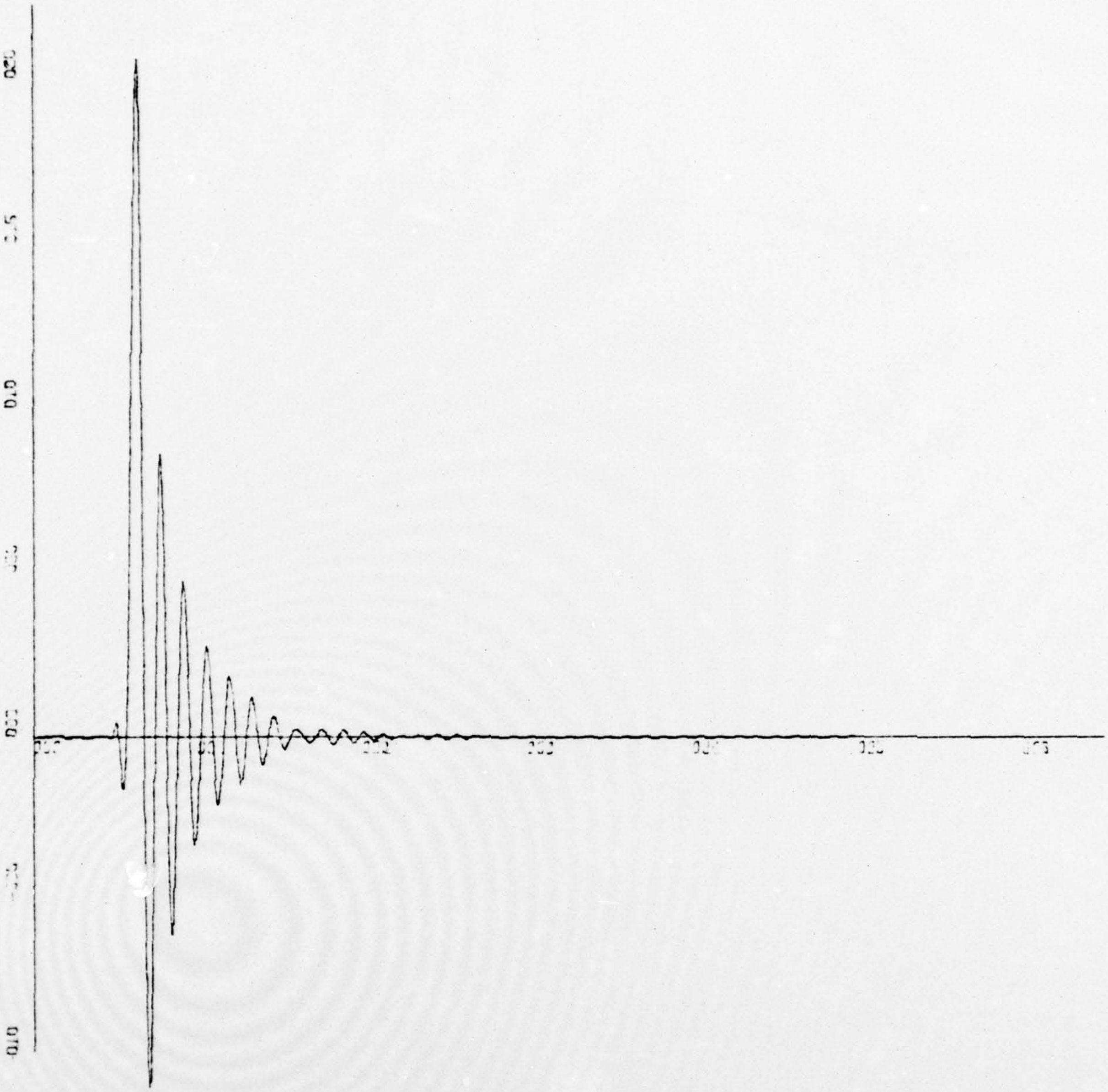
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.
AGRT63 , TURN 20 KN.
PLØT IS ROLL ANGLE VERSUS TIME

PLOT 23

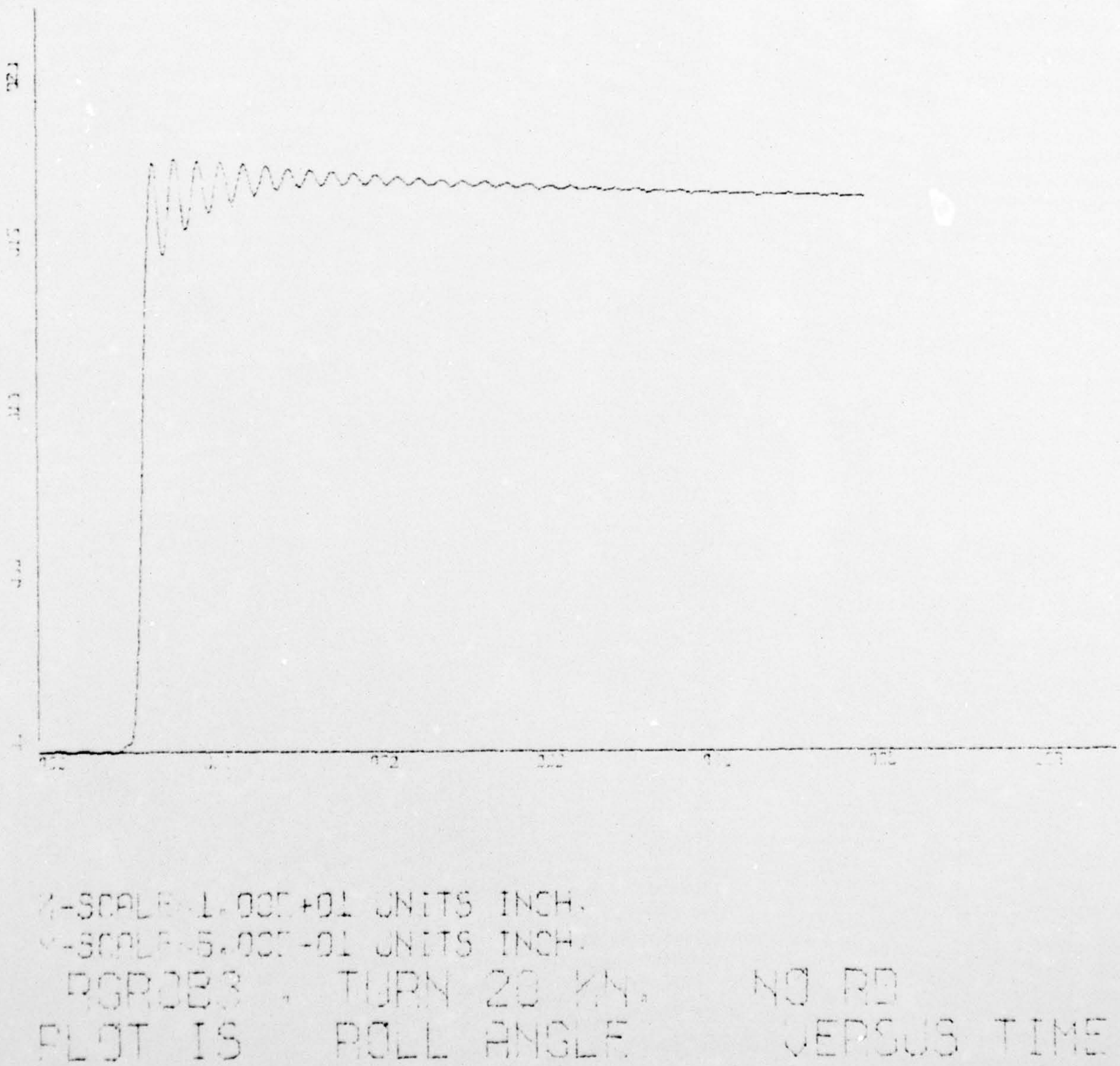
for applied parameters see first page of this appendix



X-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 5.00E-01 UNITS INCH.
RGRT63 . TURN 20 KN.
PLOT IS ROLL RATE VERSUS TIME

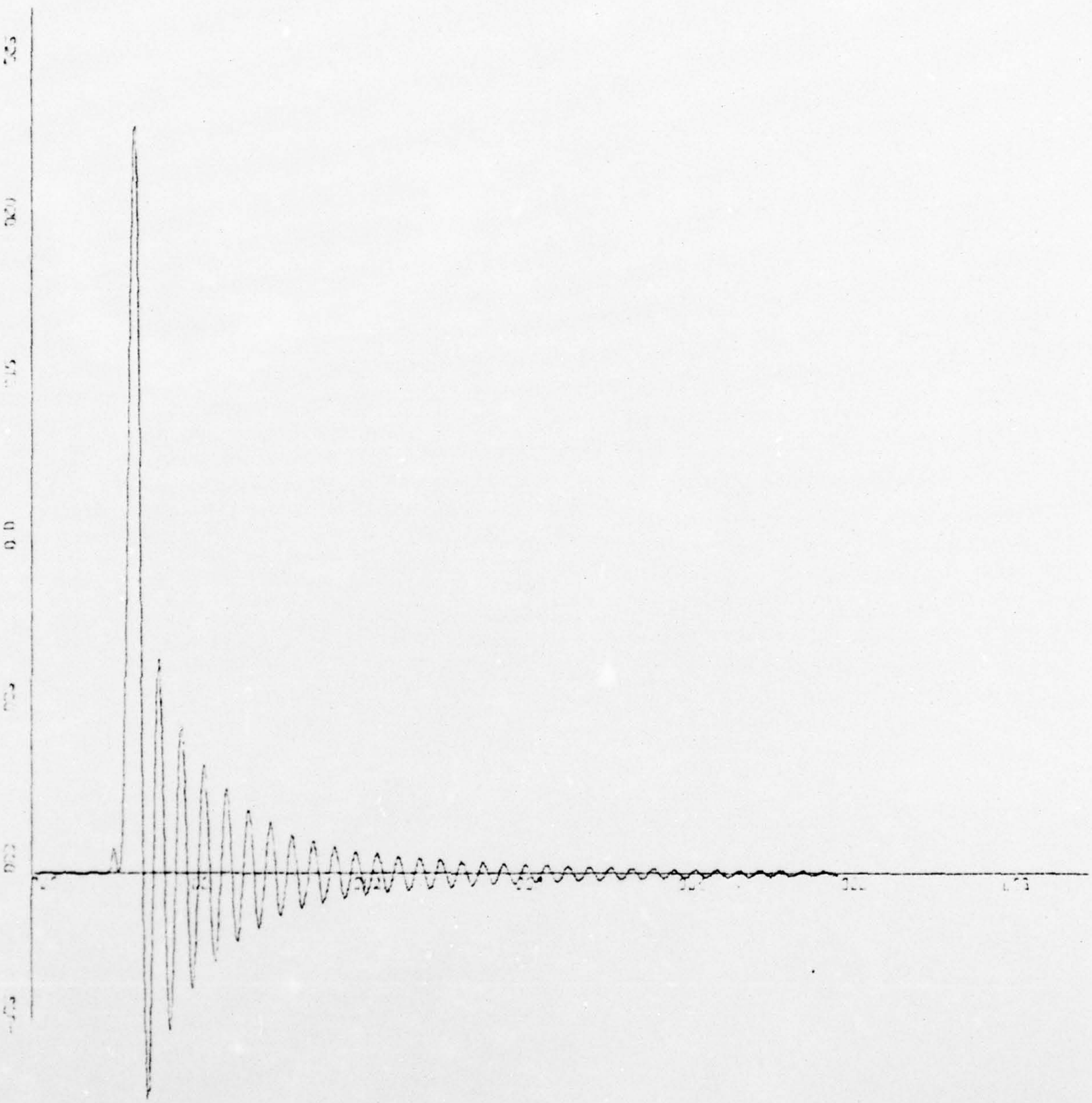
PLOT 24

for applied parameters see first page of this appendix



PLOT 25

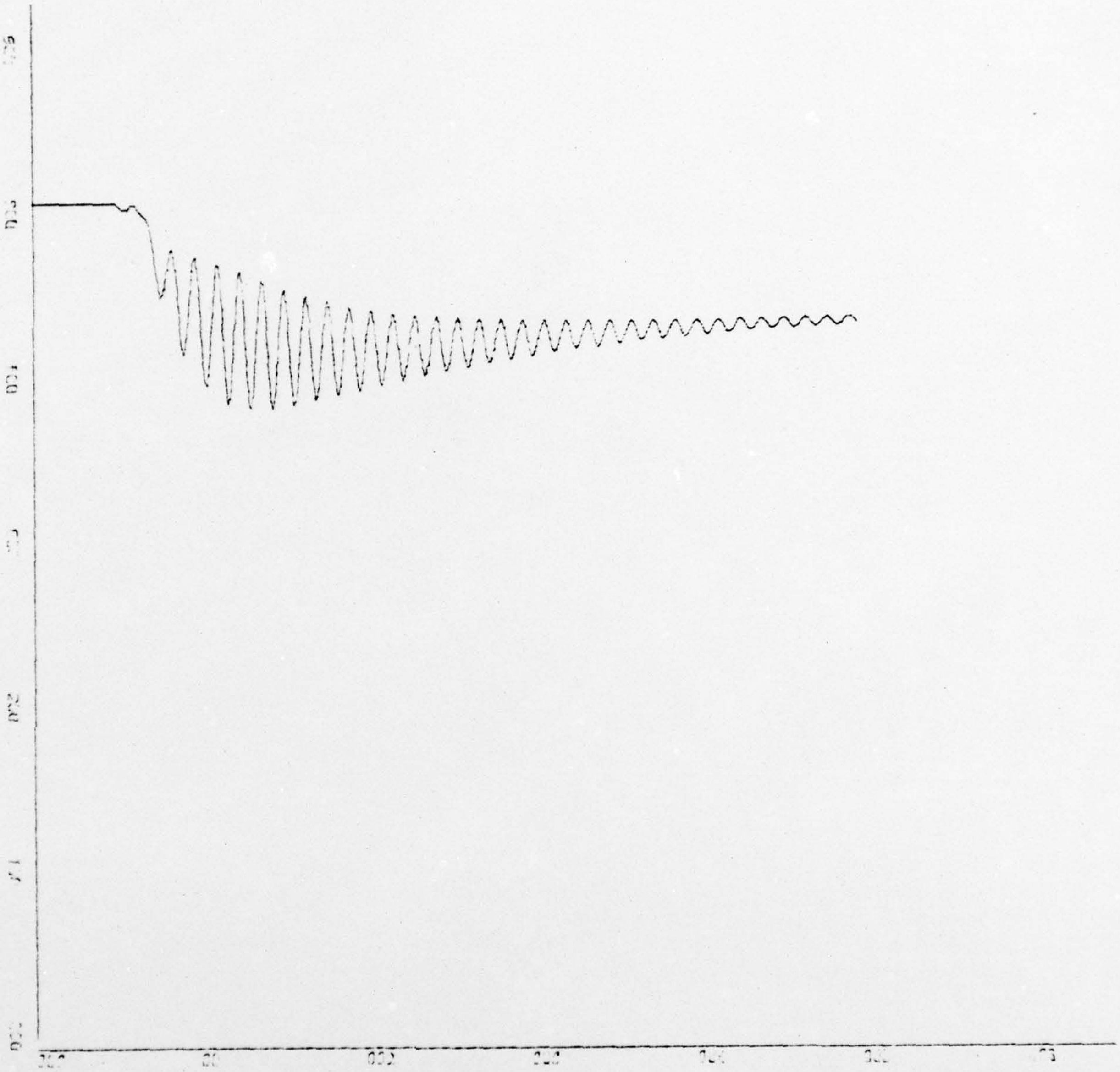
for applied parameters, see first page of this appendix



X-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 5.00E-01 UNITS INCH.
RGR083 TURN 20 KN. NO RD
PLOT IS ROLL RATE VERSUS TIME

PLOT 26

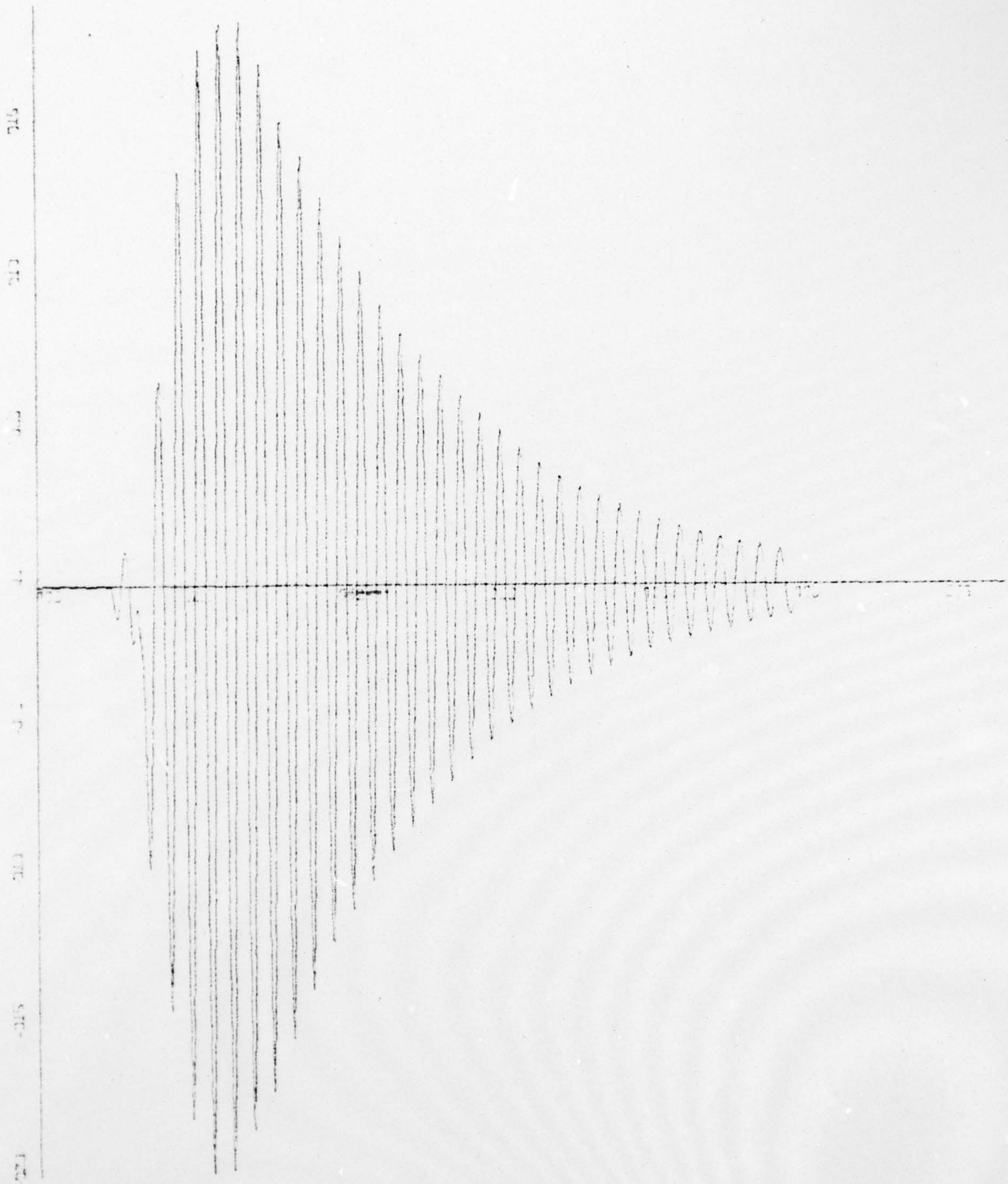
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=1.00E-01 UNITS INCH.
AGRO83 . TURN 20 KN. . NO RD
PLOT IS PITCH ANGLE VERSUS TIME

PLOT 27

for applied parameters see first page of this appendix



PLOT IS PITCH RATE VERSUS TIME

X-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 5.00E-02 UNITS INCH.

PLOT 28

for applied parameters see first page of this appendix

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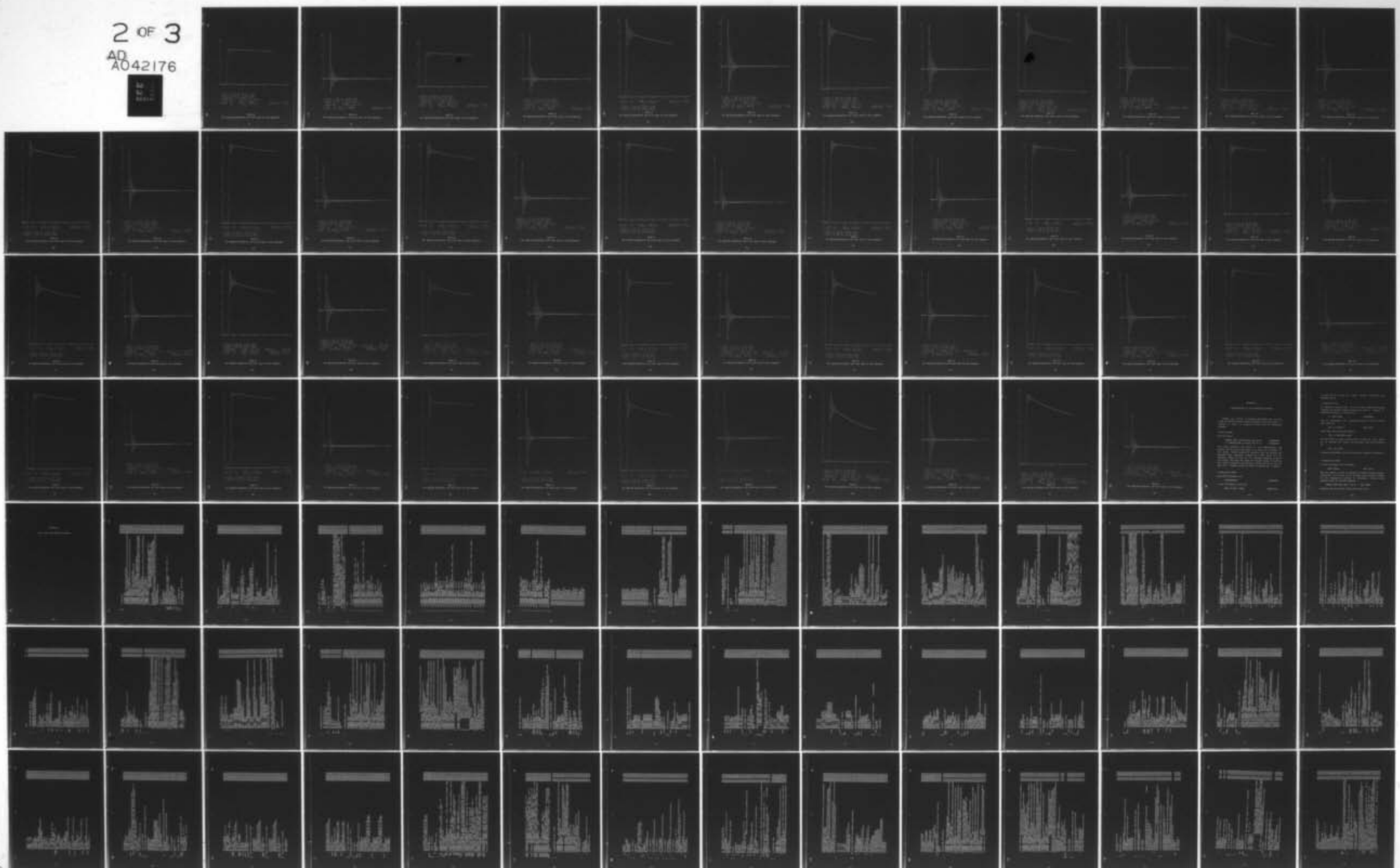
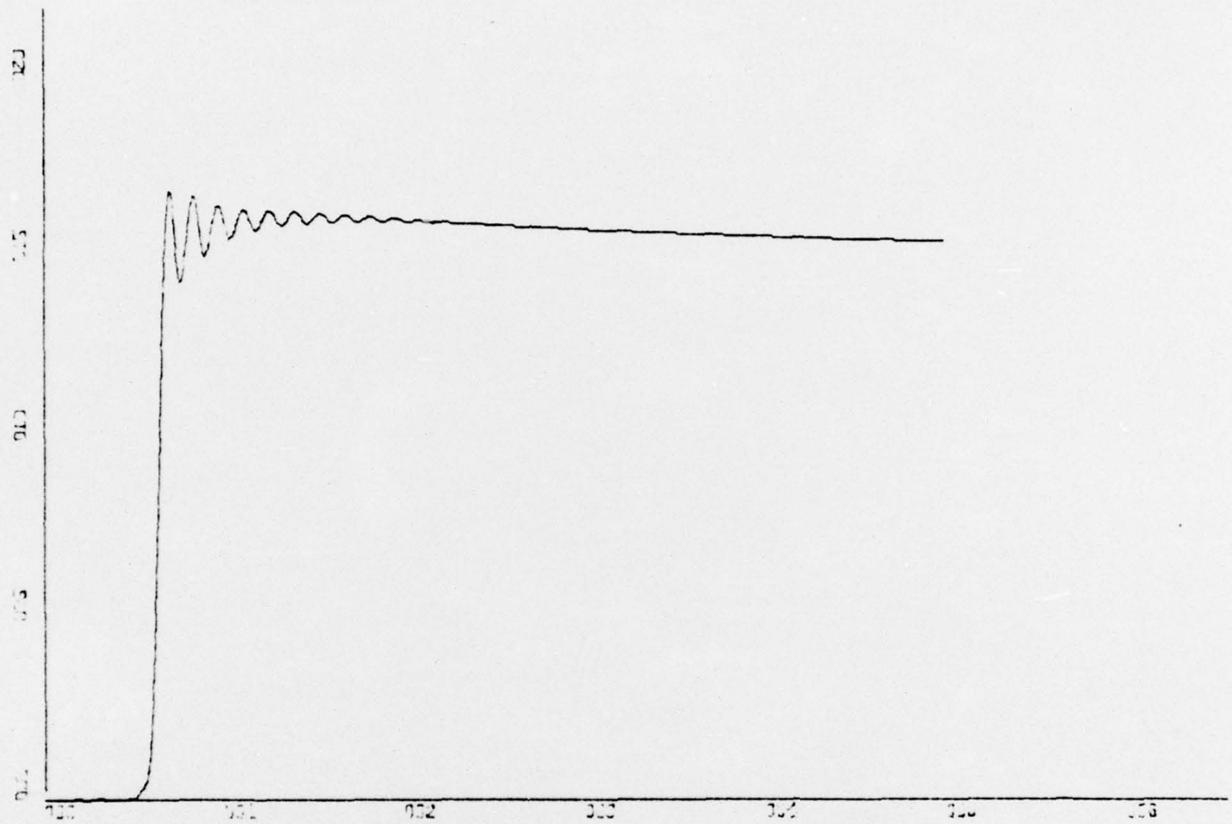
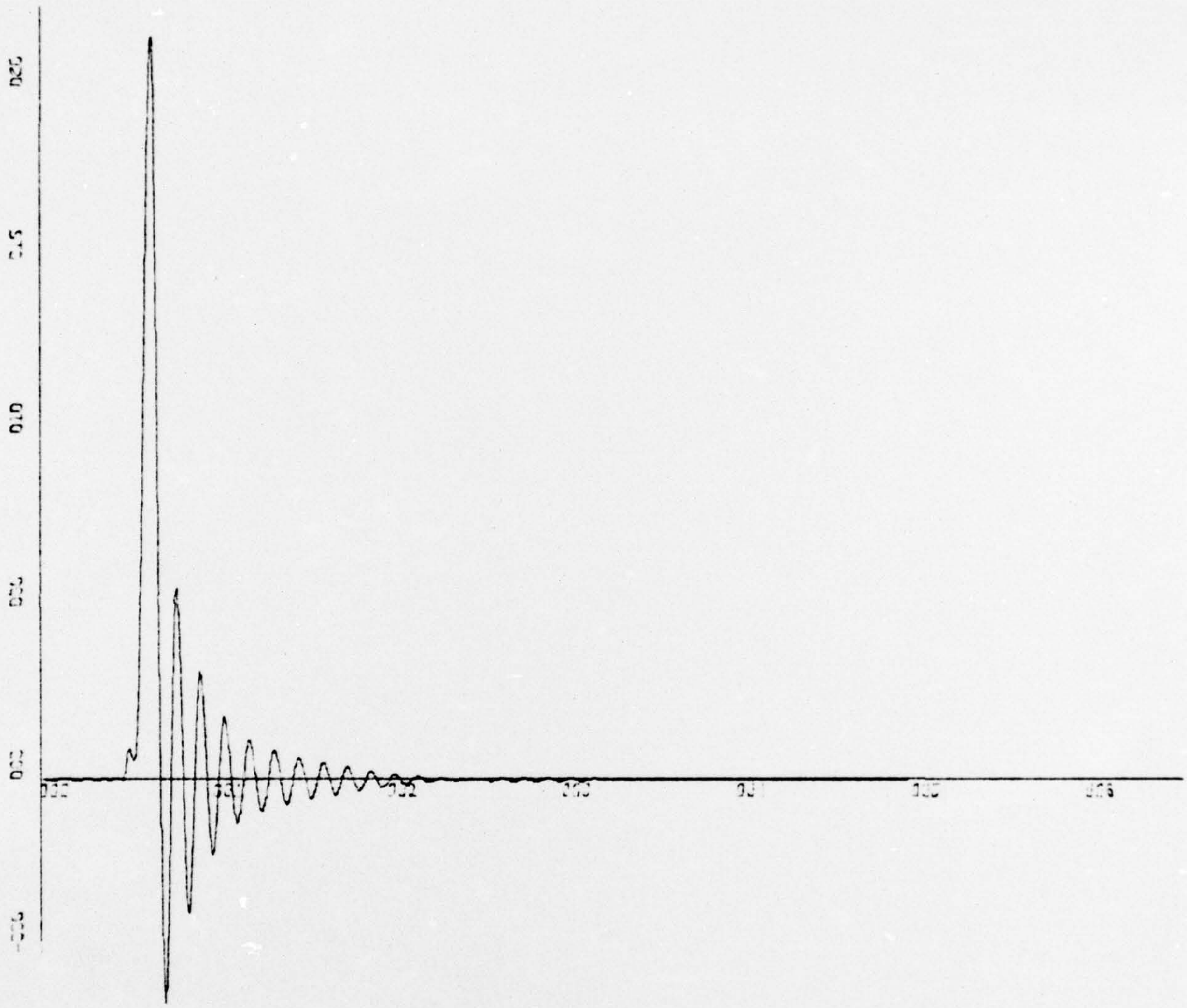




X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGRT81 , TURN 20 KN.
PLØT IS RØLL ANGLE VERSUS TIME

PLOT 29

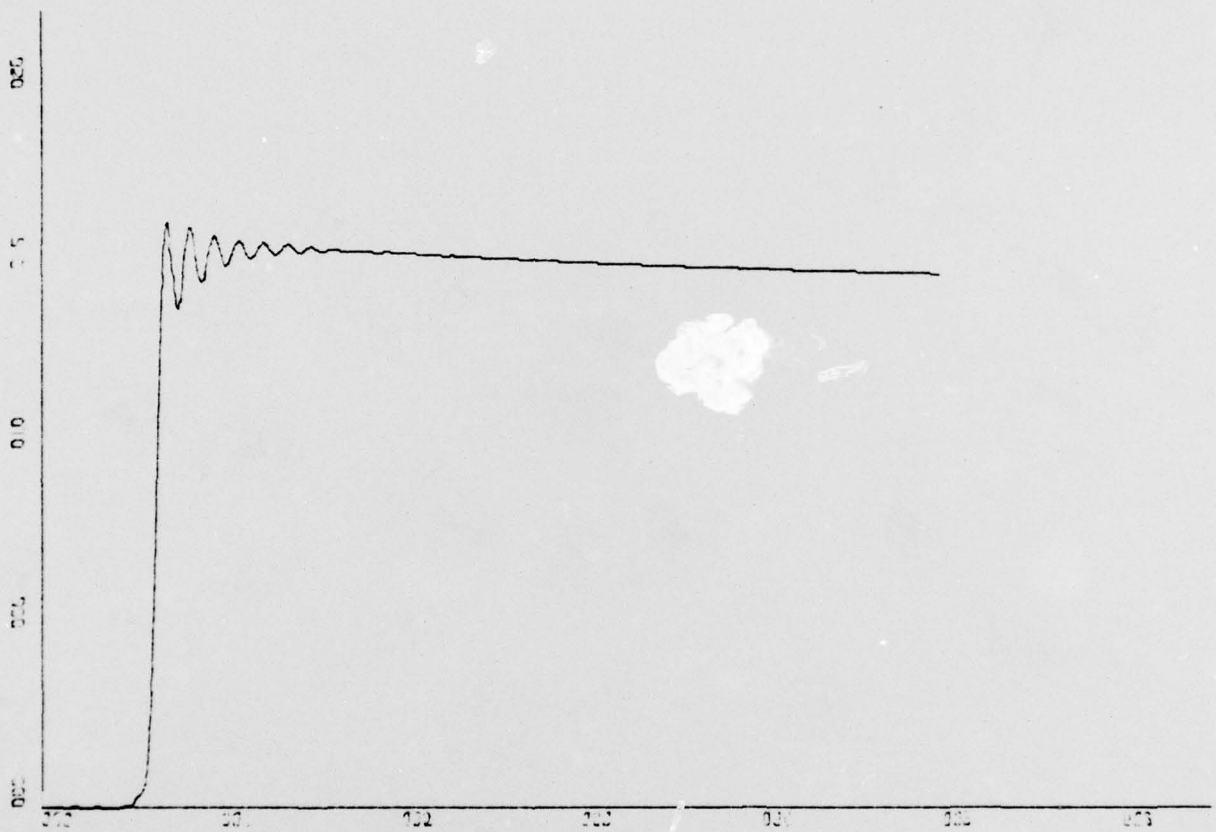
for applied parameters see first page of this appendix



K-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGRT81 , TURN 20 KN.
PLOT IS ROLL RATE VERSUS TIME

PLOT 30

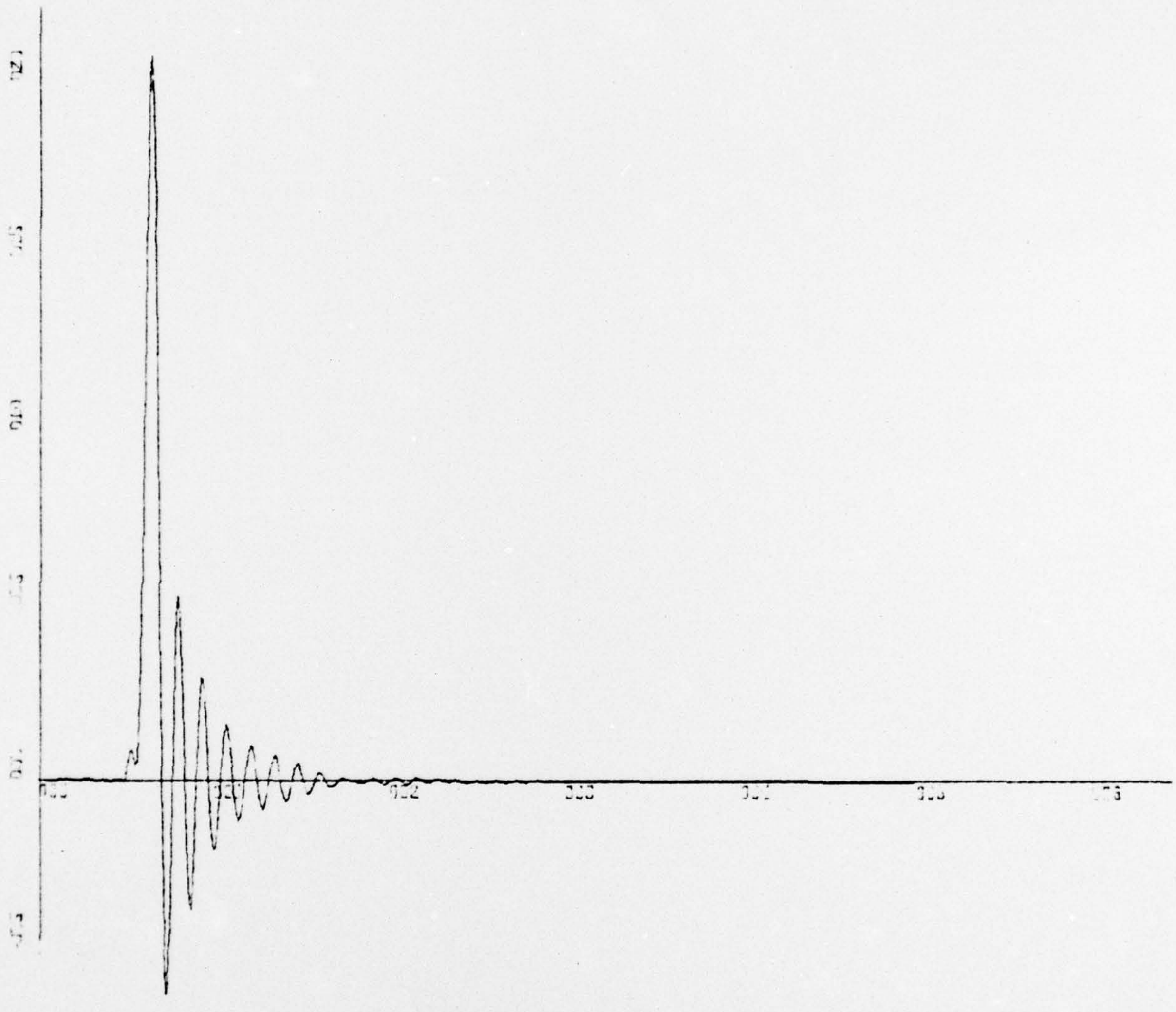
for applied parameters see first page of this appendix



X-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 5.00E-01 UNITS INCH.
RGRT82 , TURN 20 KN.
PLOT IS ROLL ANGLE VERSUS TIME

PLOT 31

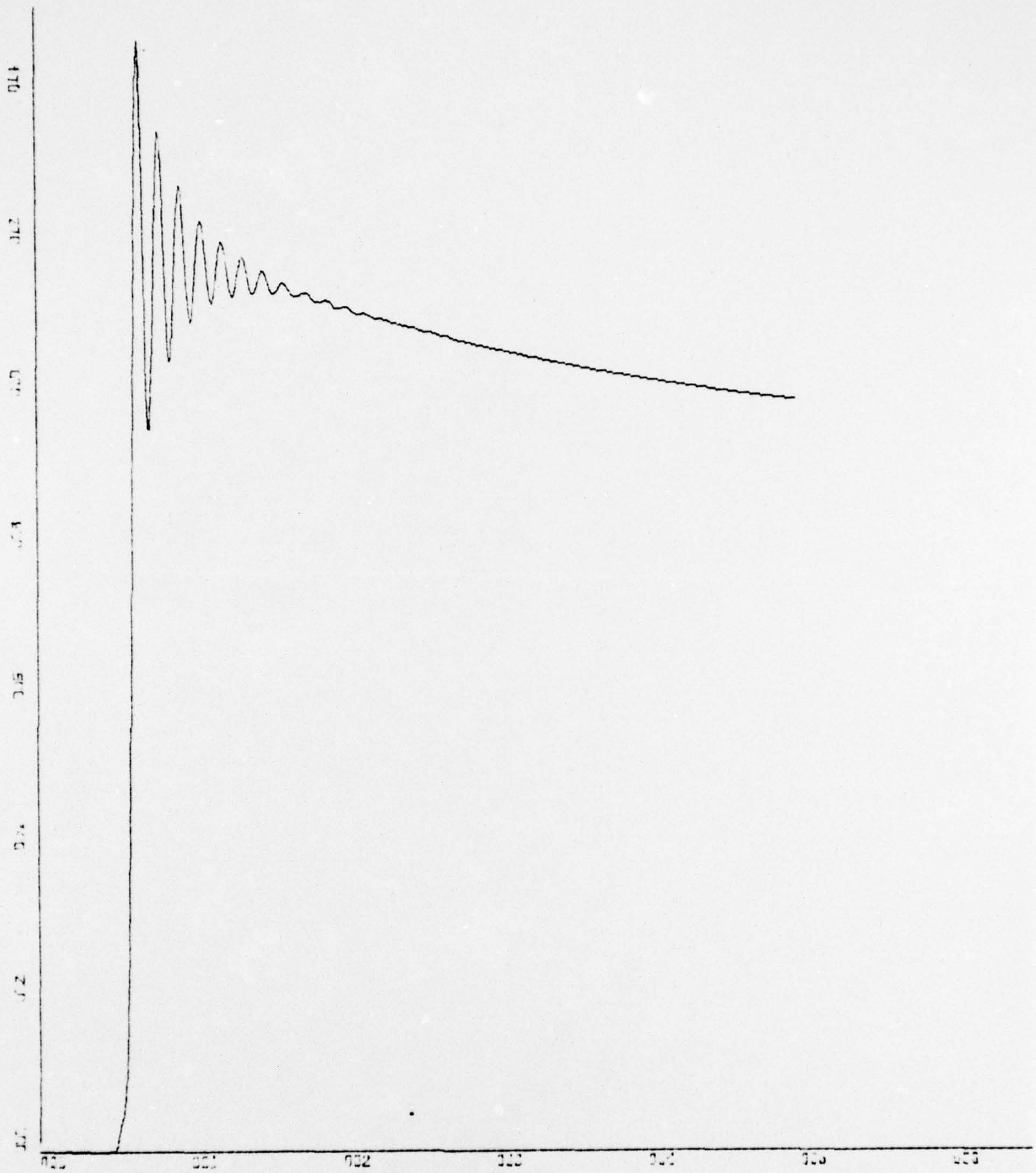
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGRT82 , TURN 20 KN.
PLØT IS RØLL RATE VERSUS TIME

PLOT 32

for applied parameters see first page of this appendix

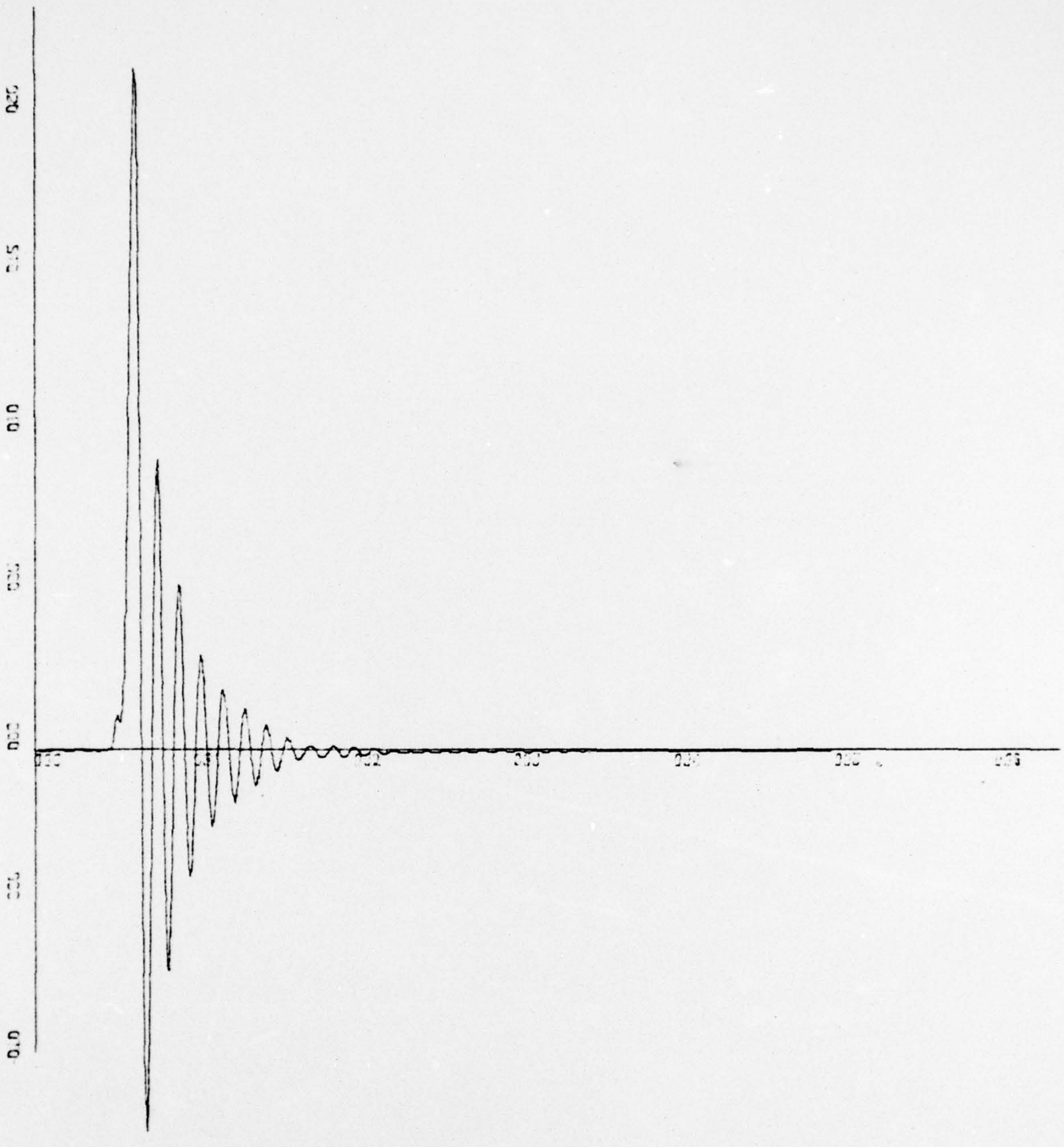


PLØT IS ROLL ANGLE VERSUS TIME

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.

PLOT 33

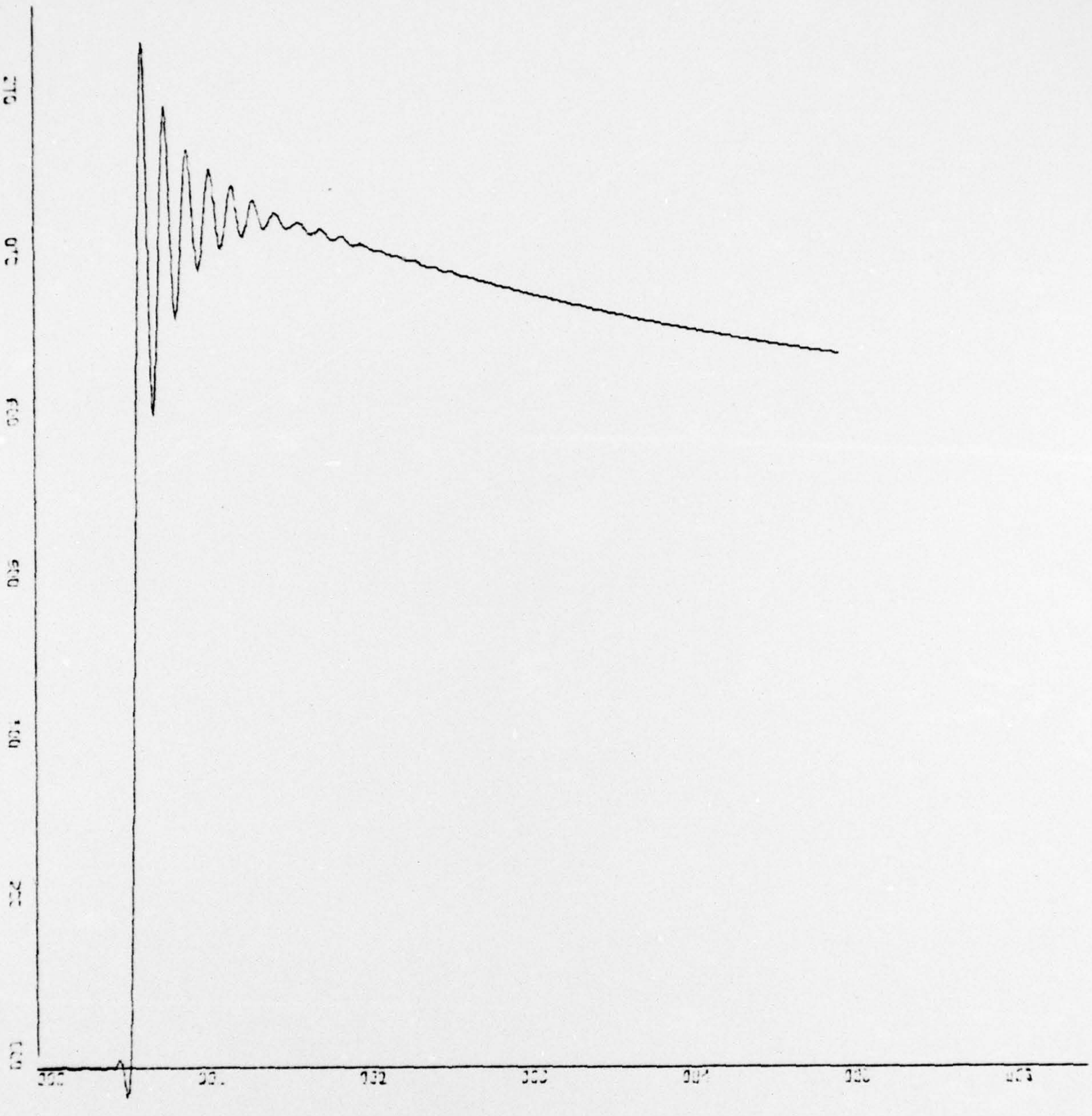
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGRTX1 , TURN 20 KN.
PLOT IS ROLL RATE VERSUS TIME

PLOT 34

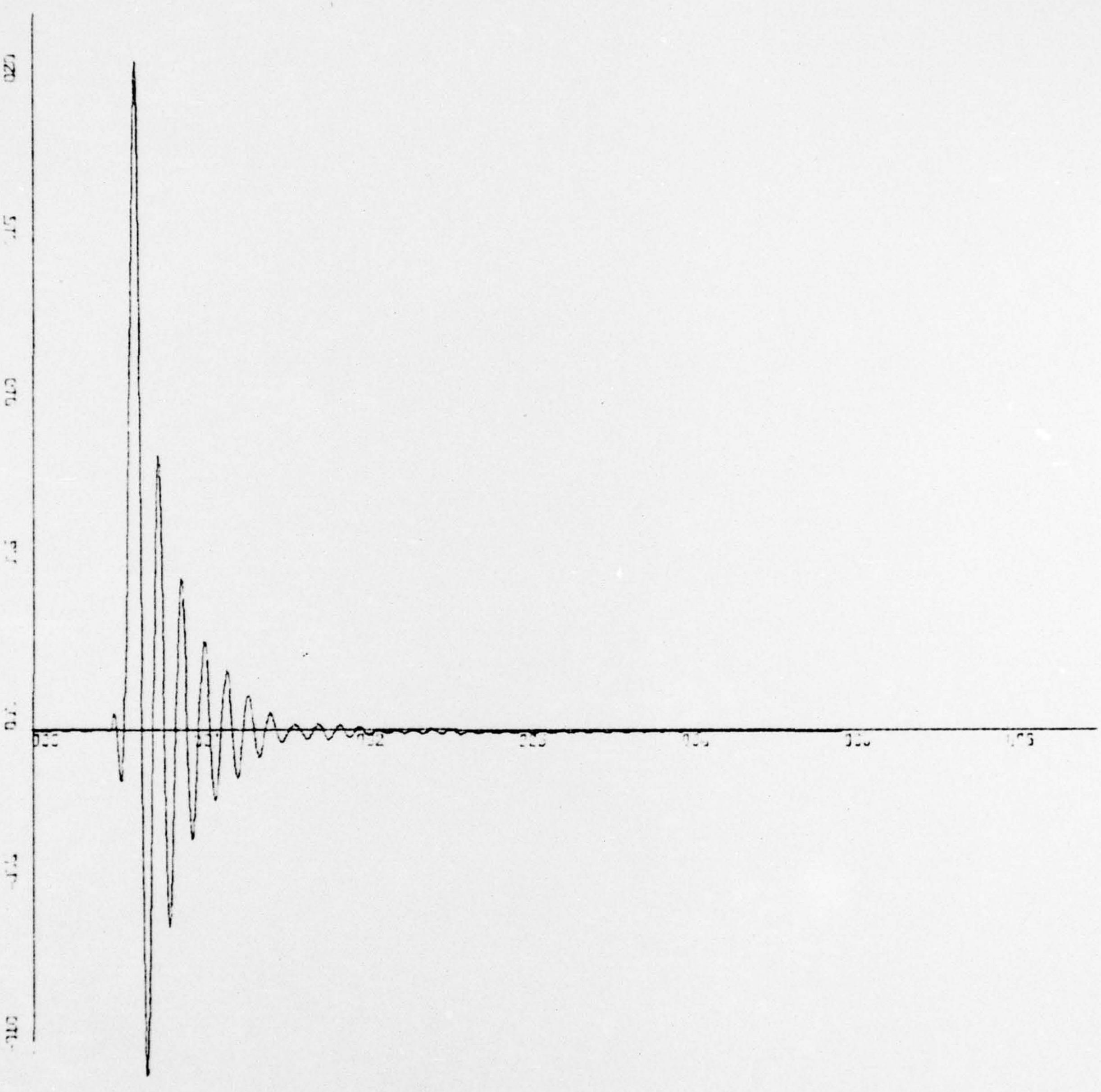
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.
RGRTX2 , TURN 20 KN.
PLOT IS ROLL ANGLE VERSUS TIME

PLOT 35

for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGRTX2 , TURN 20 KN.
PLØT IS RØLL RATE VERSUS TIME

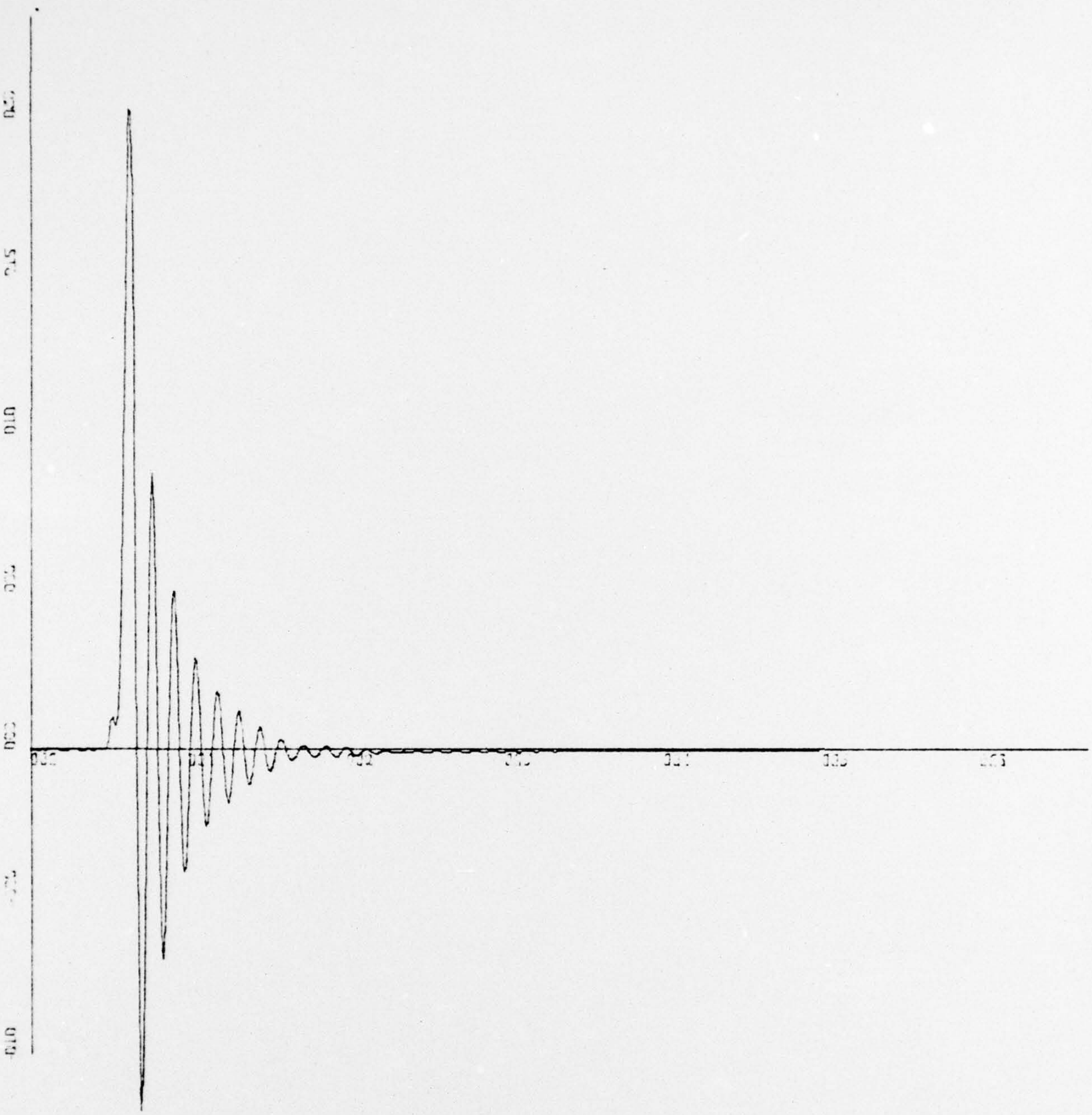
PLOT 36

for applied parameters see first page of this appendix

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.
RGRTX3 , TURN 20 KN.
PLØT IS RØLL ANGLE VERSUS TIME

PLOT 37

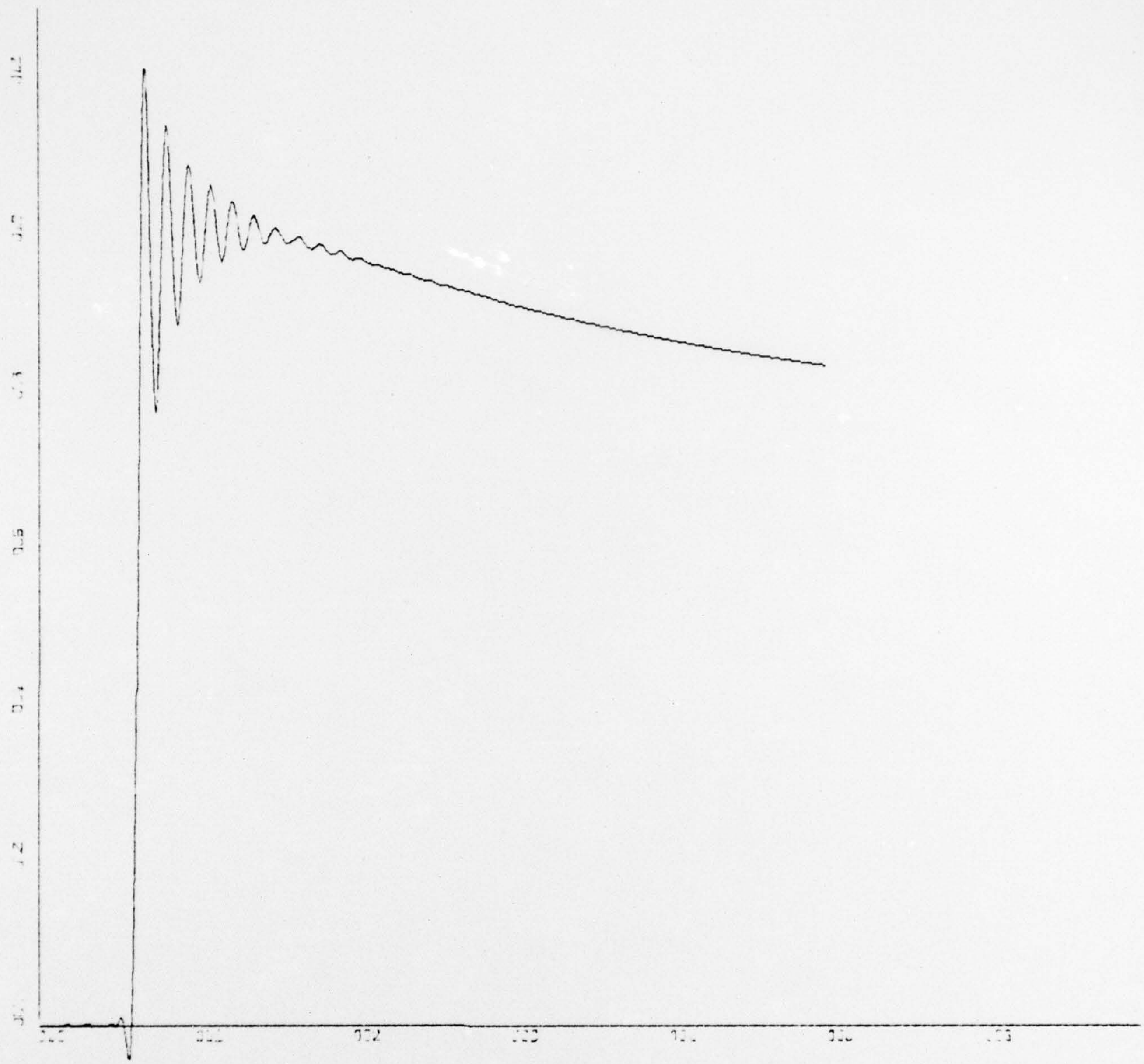
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGRTX3 , TURN 20 KN.
PLOT IS ROLL RATE VERSUS TIME

PLOT 38

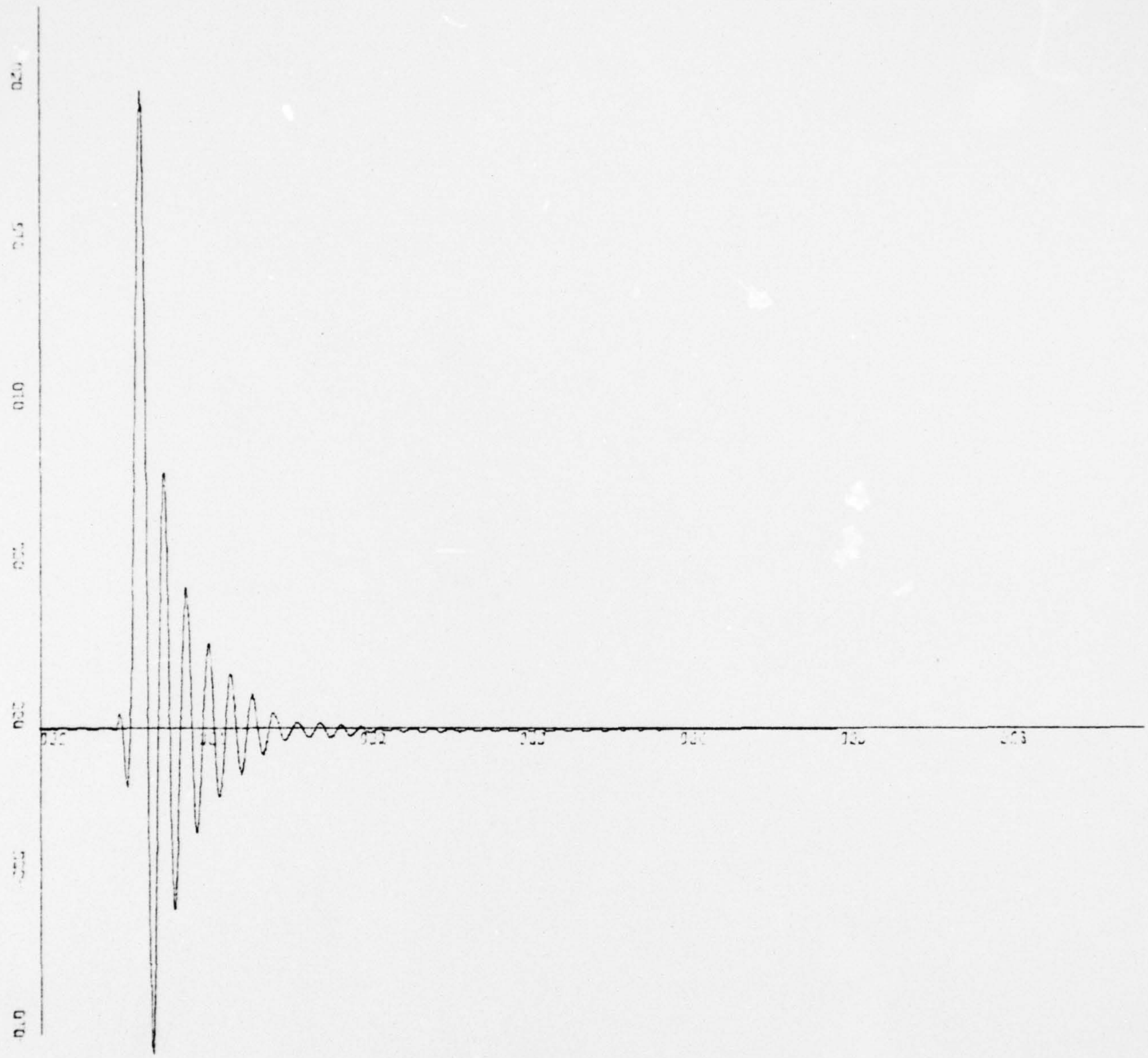
for applied parameters see first page of this appendix



X-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 2.00E-01 UNITS INCH.
AGRTX4 , TURN 20 KN.
PLØT IS ROLL ANGLE VERSUS TIME

PLOT 39

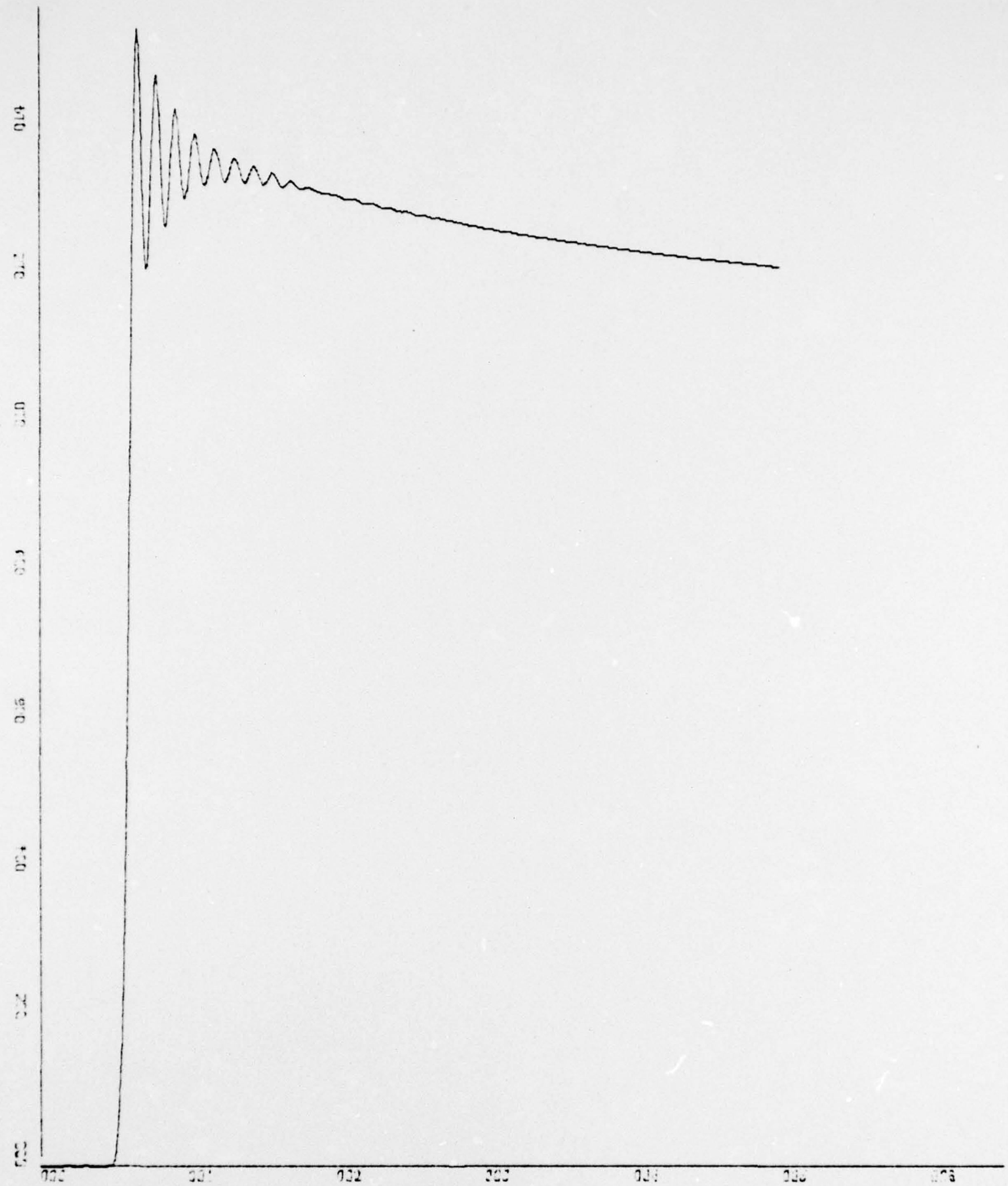
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGRTX4 , TURN 20 KN.
PLOT IS ROLL RATE VERSUS TIME

PLOT 40

for applied parameters see first page of this appendix

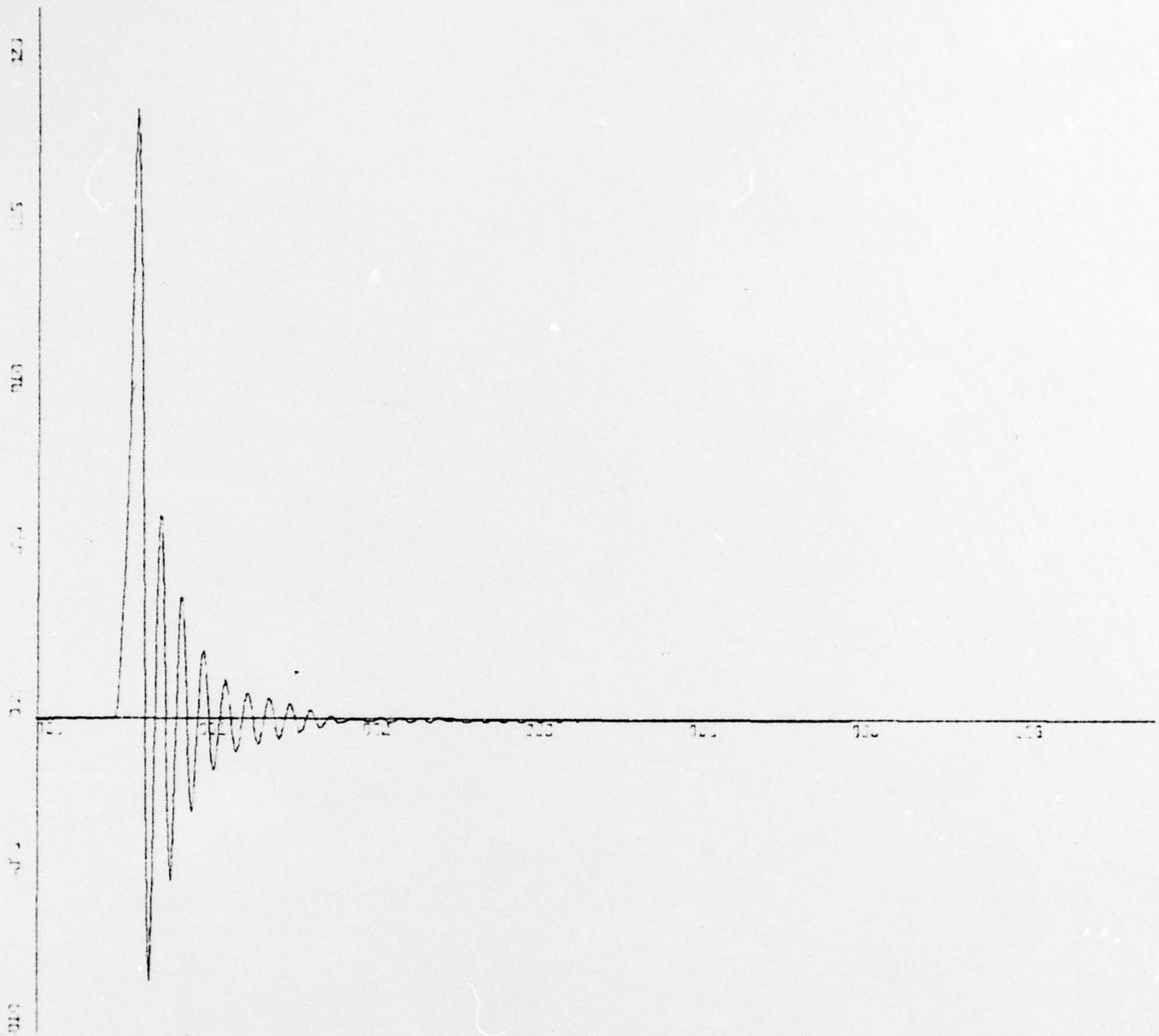


PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.

PLOT 41

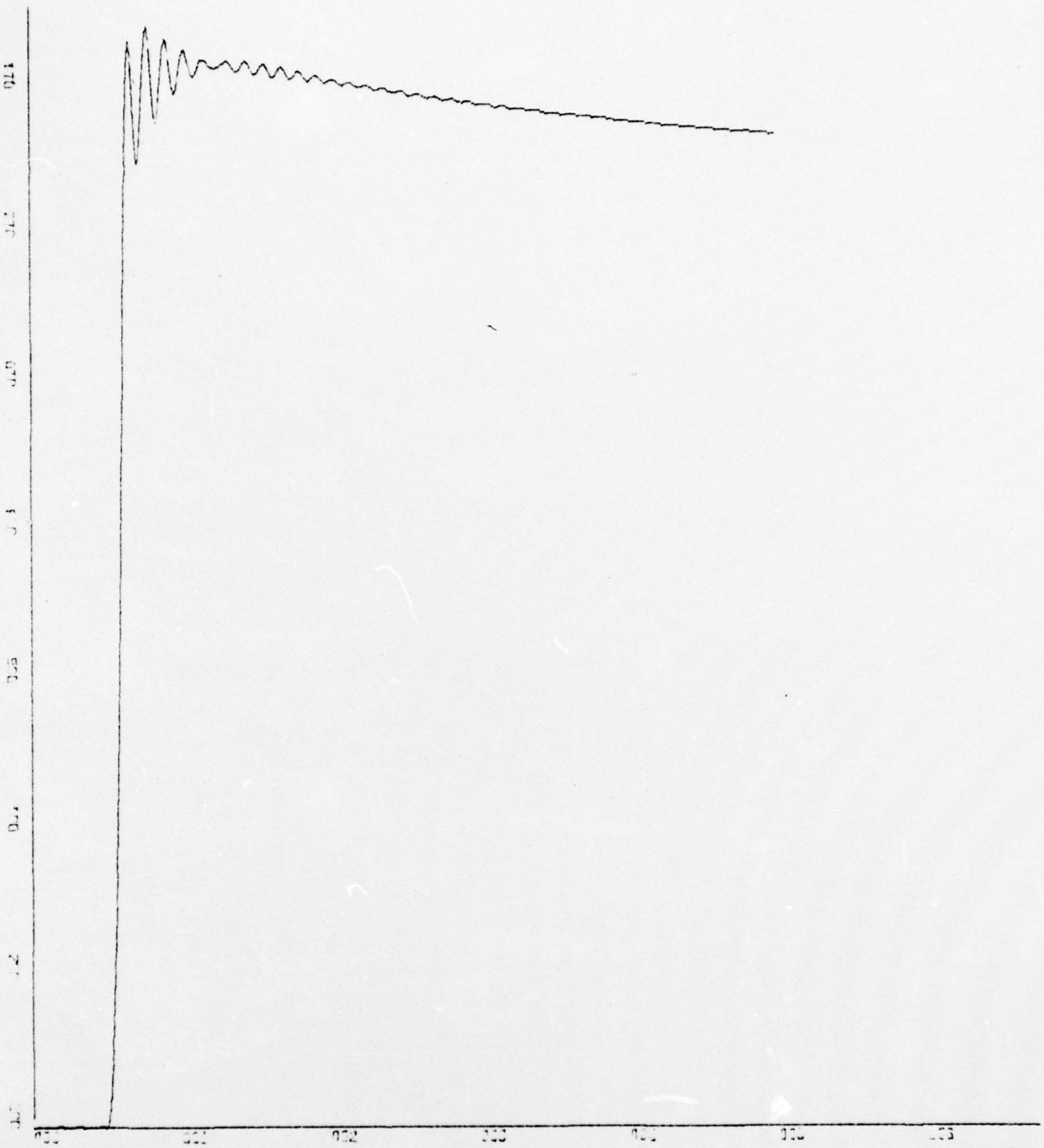
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGRT11 , TURN 20 KN.
PLØT IS RØLL RATE VERSUS TIME

PLOT 42

for applied parameters see first page of this appendix

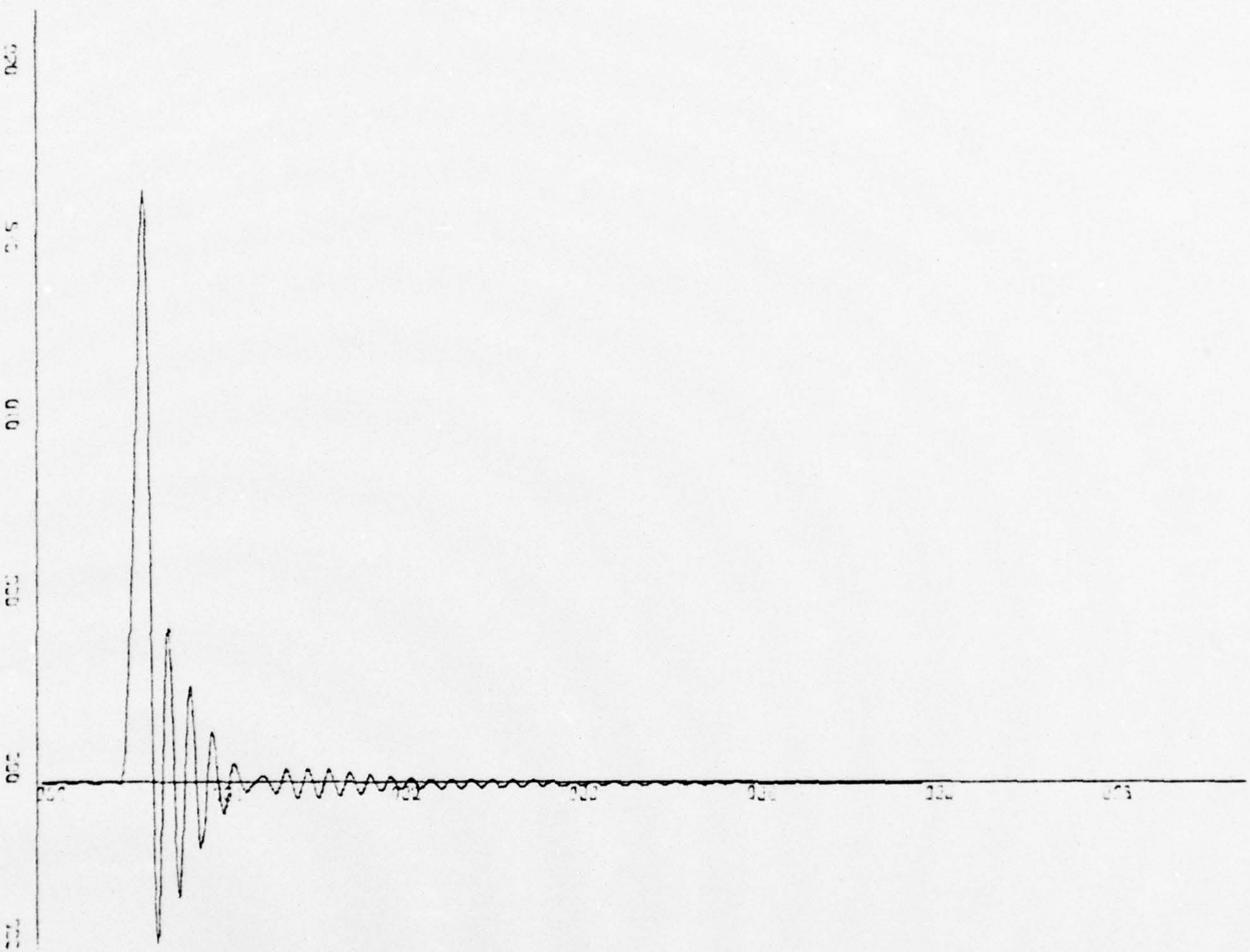


PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.

PLOT 43

for applied parameters see first page of this appendix



K-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGRT12 , TURN 20 KN.
PLOT IS ROLL RATE VERSUS TIME

PLOT 44

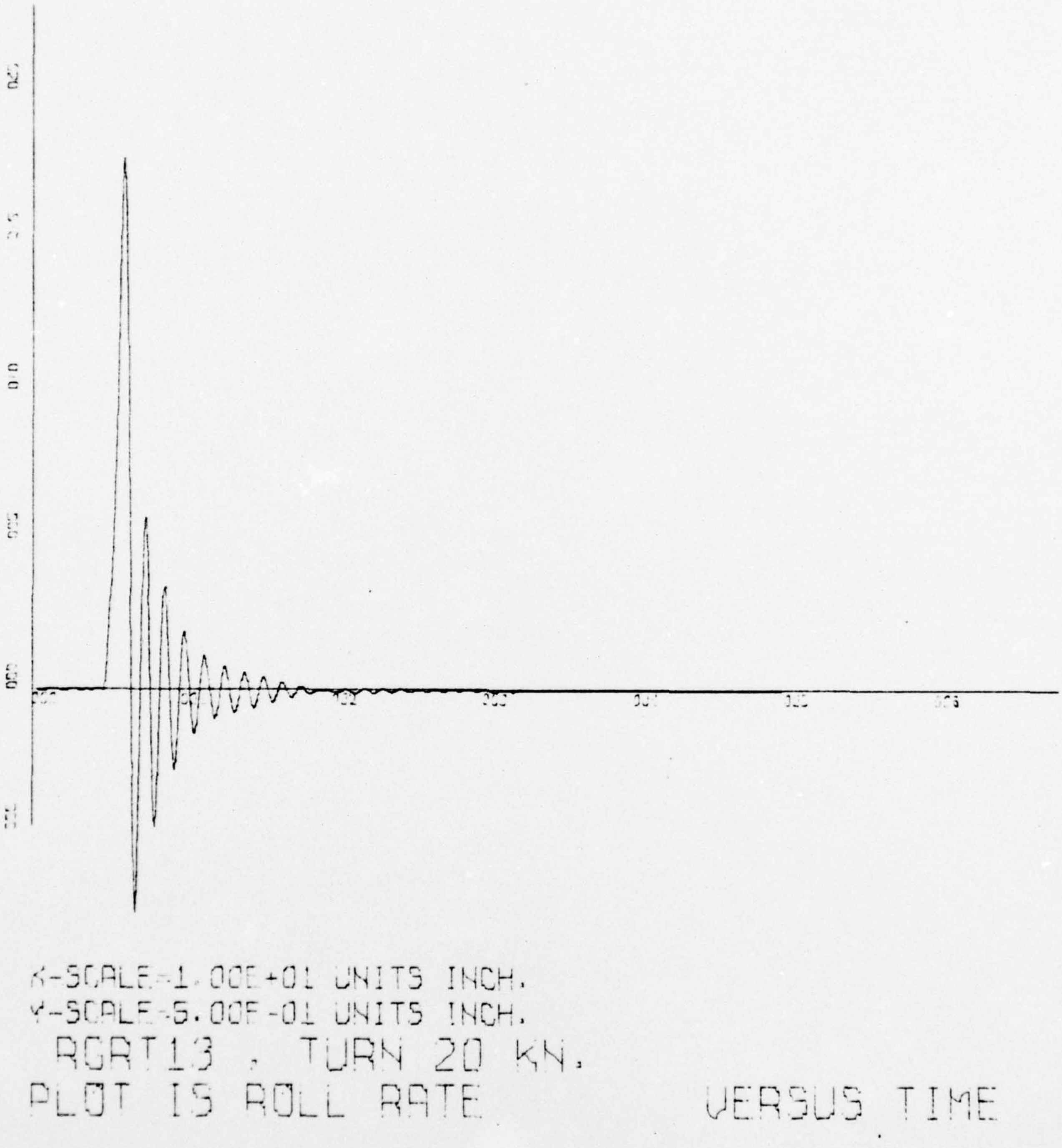
for applied parameters see first page of this appendix

PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.

PLOT 45

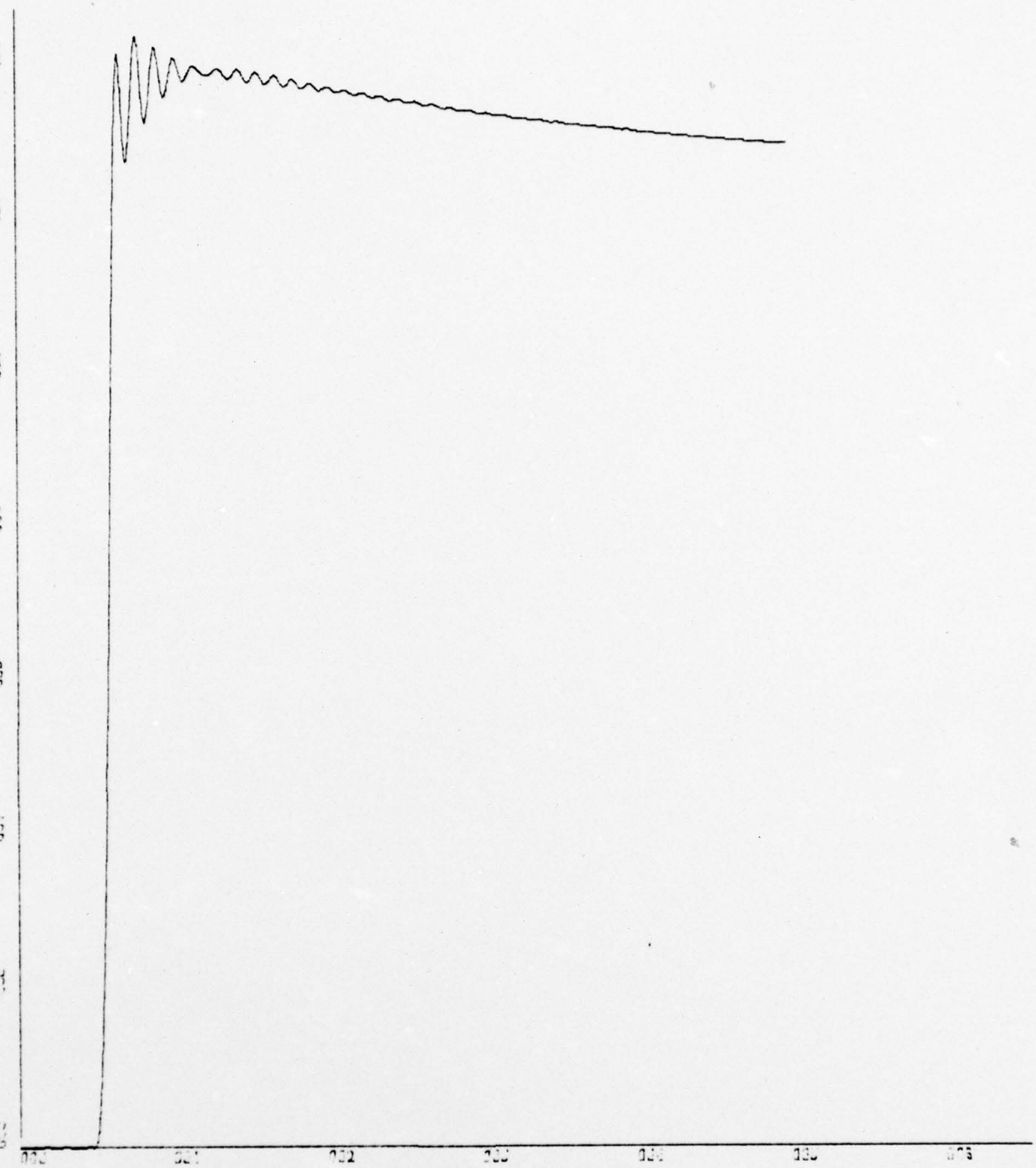
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGRT13 , TURN 20 KN.
PLOT IS ROLL RATE VERSUS TIME

PLOT 46

for applied parameters see first page of this appendix

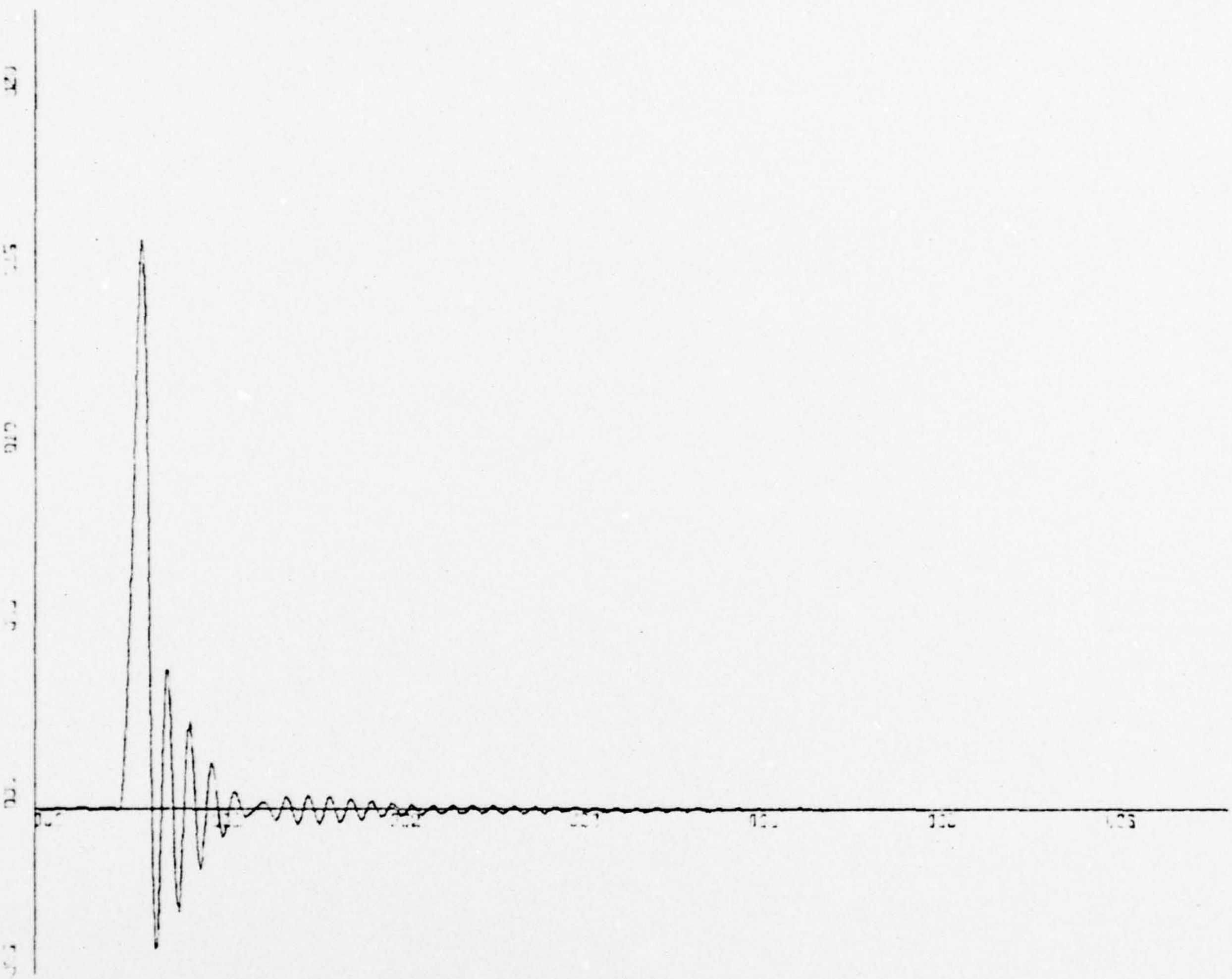


PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.

PLOT 47

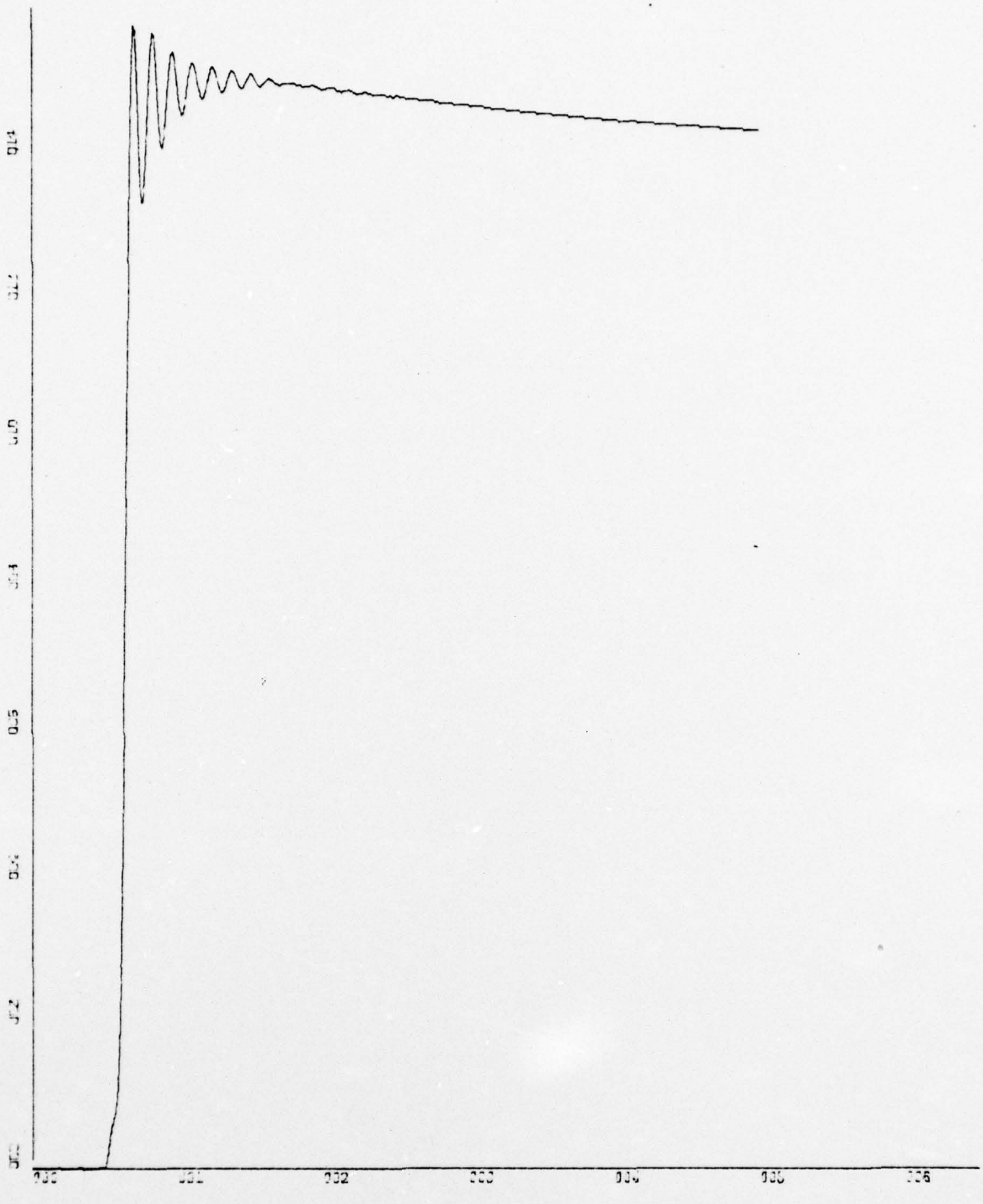
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGRT14 , TURN 20 KN.
PLØT IS RØLL RATE VERSUS TIME

PLOT 48

for applied parameters see first page of this appendix

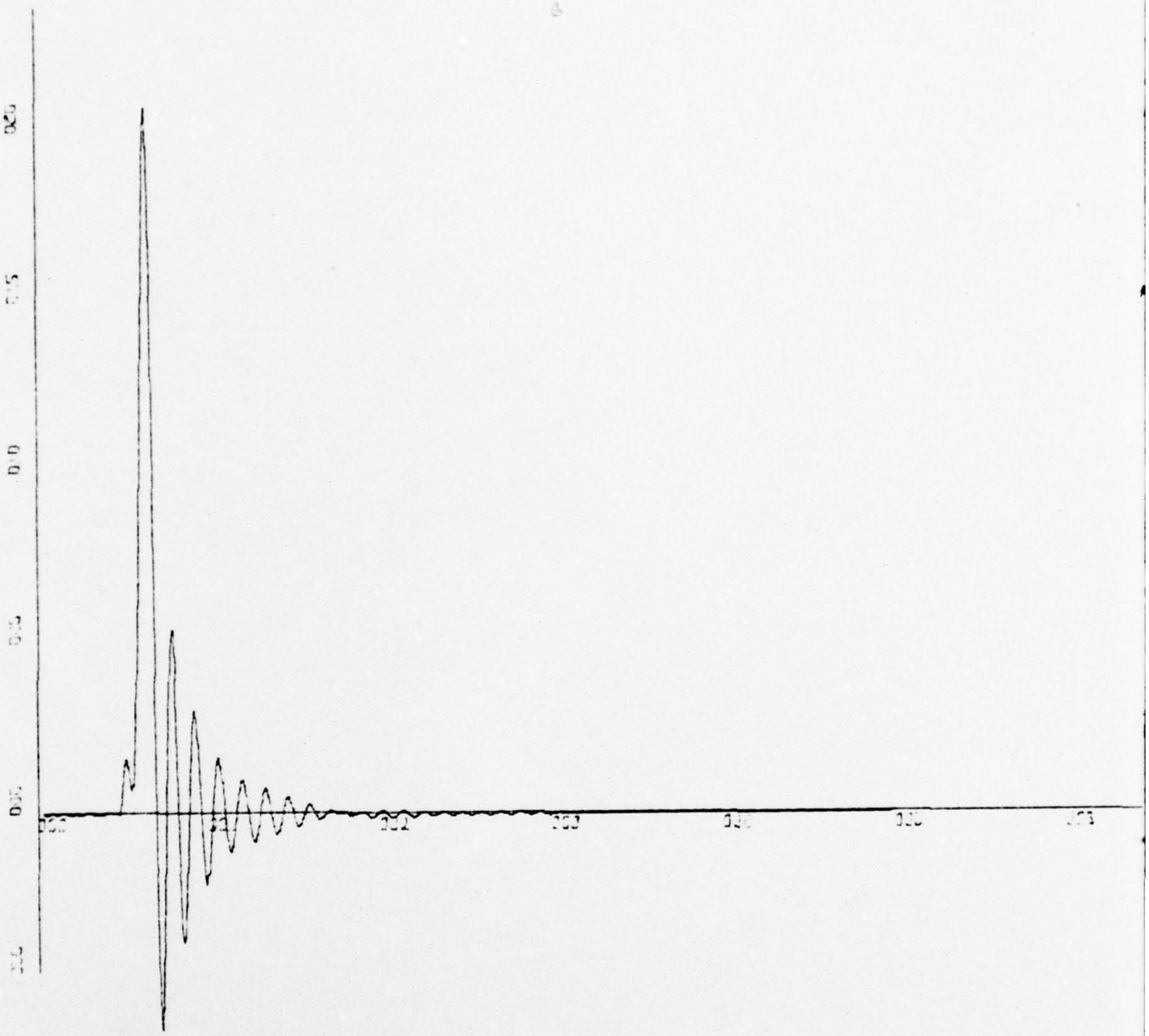


PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.

PLOT 49

for applied parameters see first page of this appendix



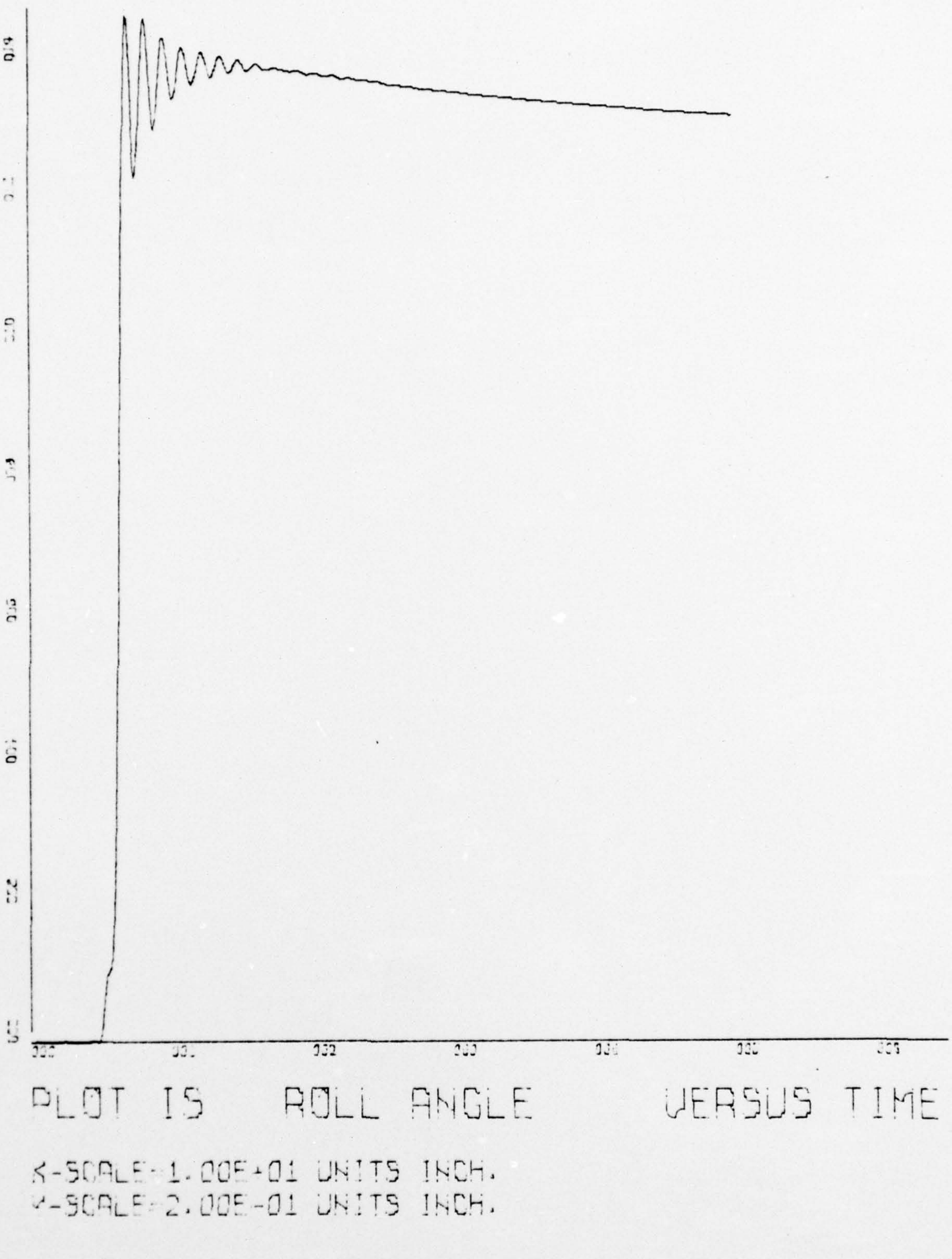
X-SCALE=1.00E-01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.

RUNOD1 , TURN 20 KN

PLOT IS ROLL RATE VERSUS TIME

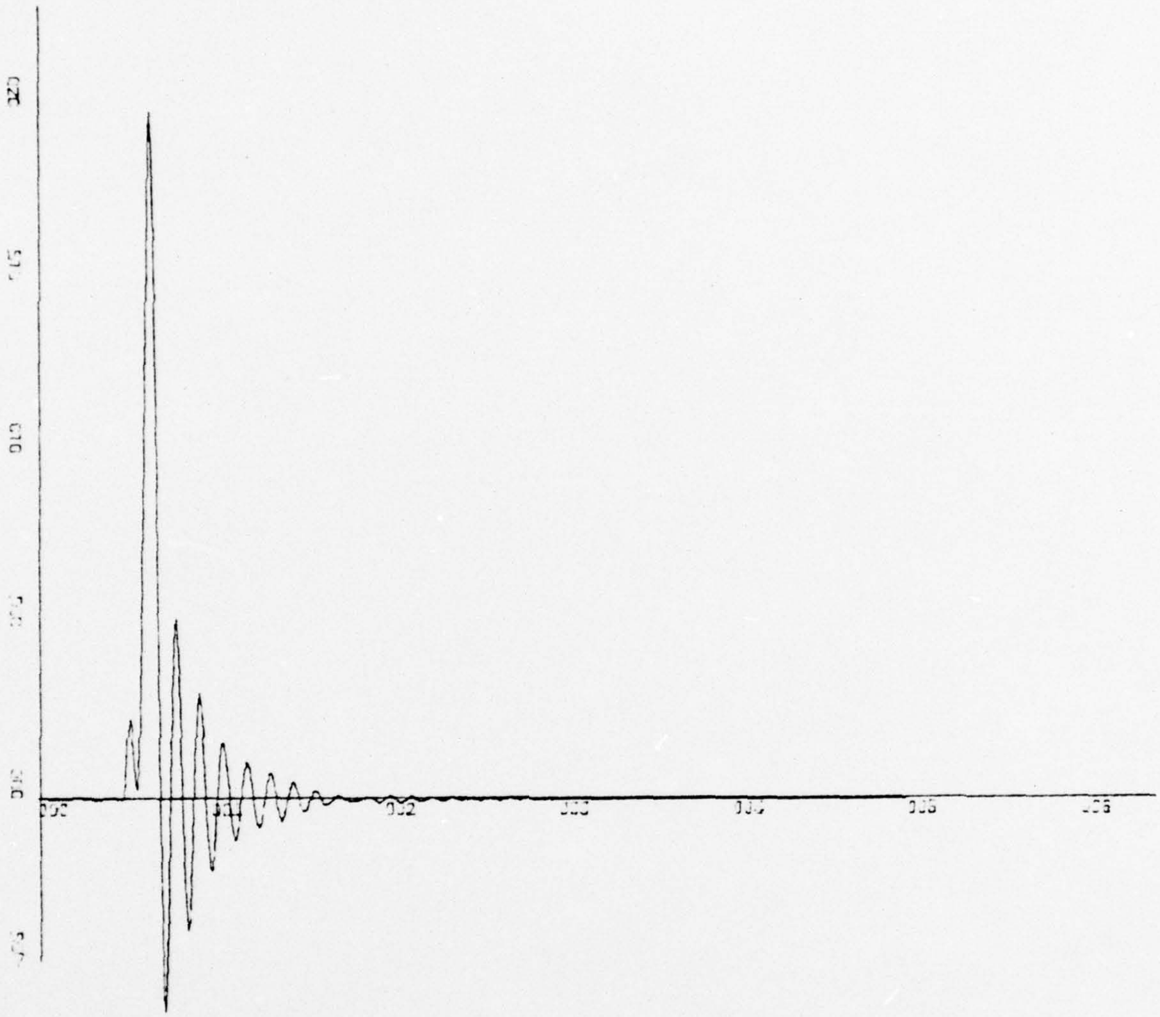
PLOT 50

for applied parameters see first page of this appendix



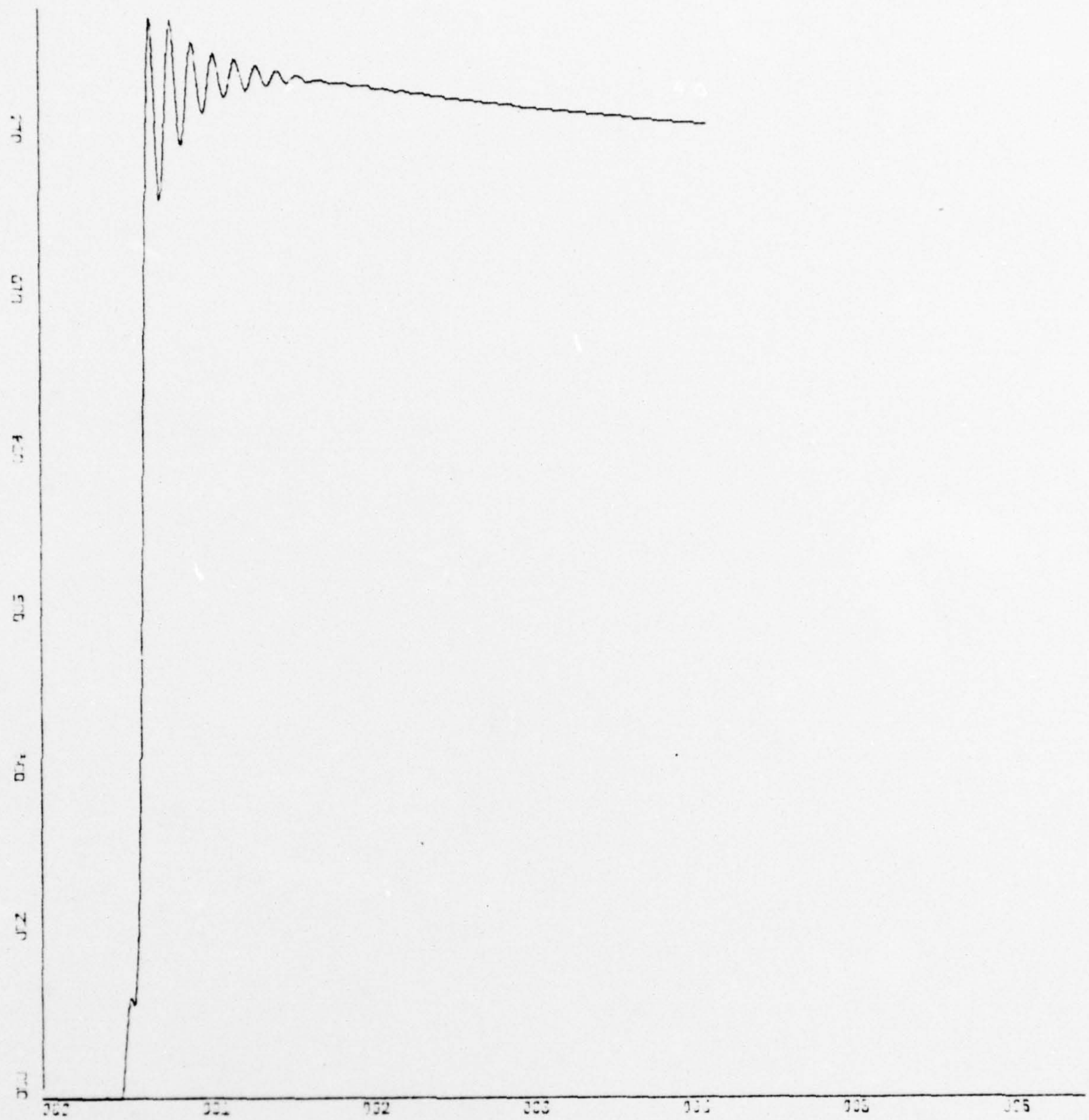
PLOT 51

for applied parameters see first page of this appendix



K-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RUNOD2 , TURN 20 KN
PLØT IS RØLL RATE VERSUS TIME

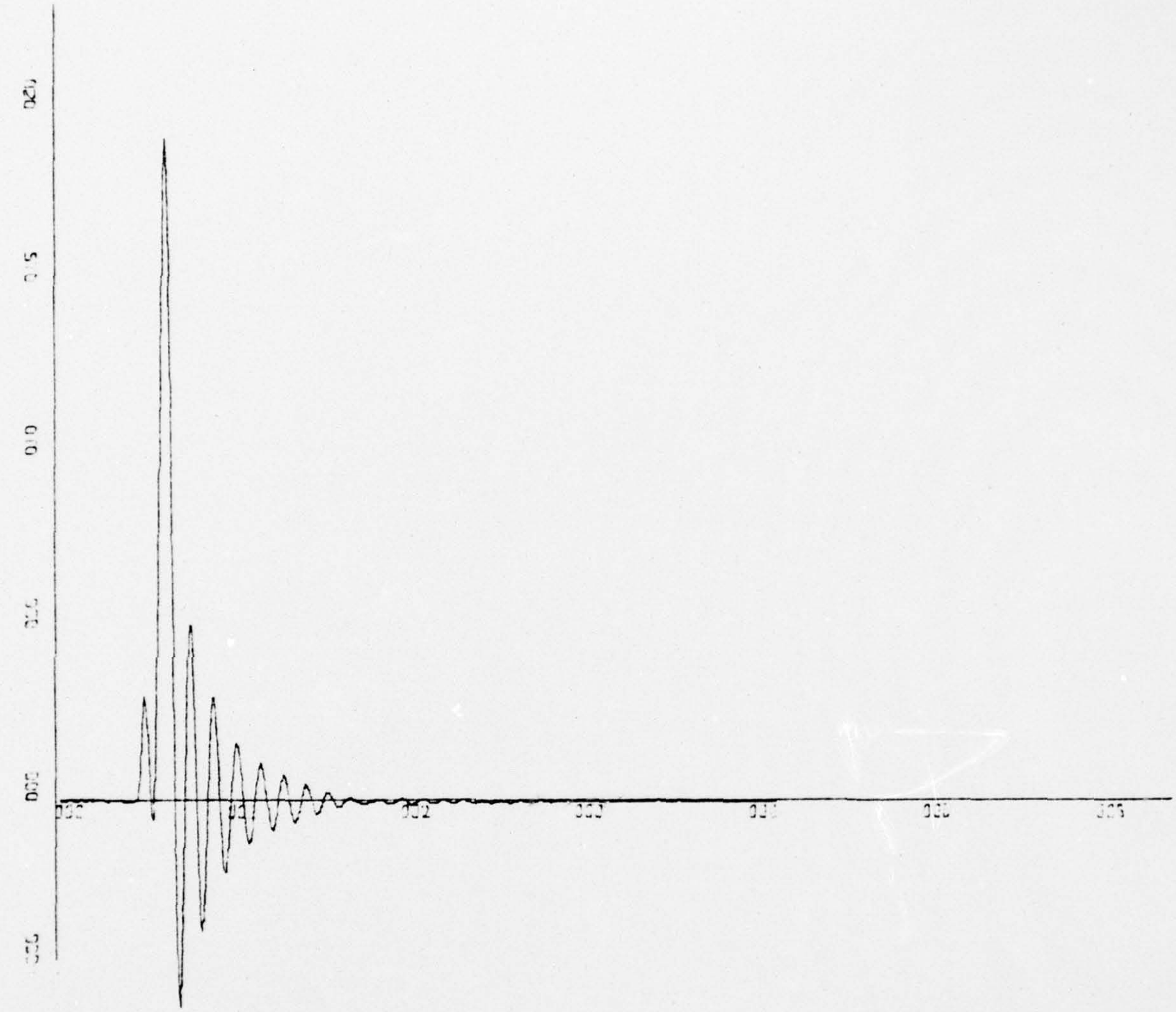
PLOT 52
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.
RUNOD3 . TURN 20 KN
PLØT IS ROLL ANGLE VERSUS TIME

PLOT 53

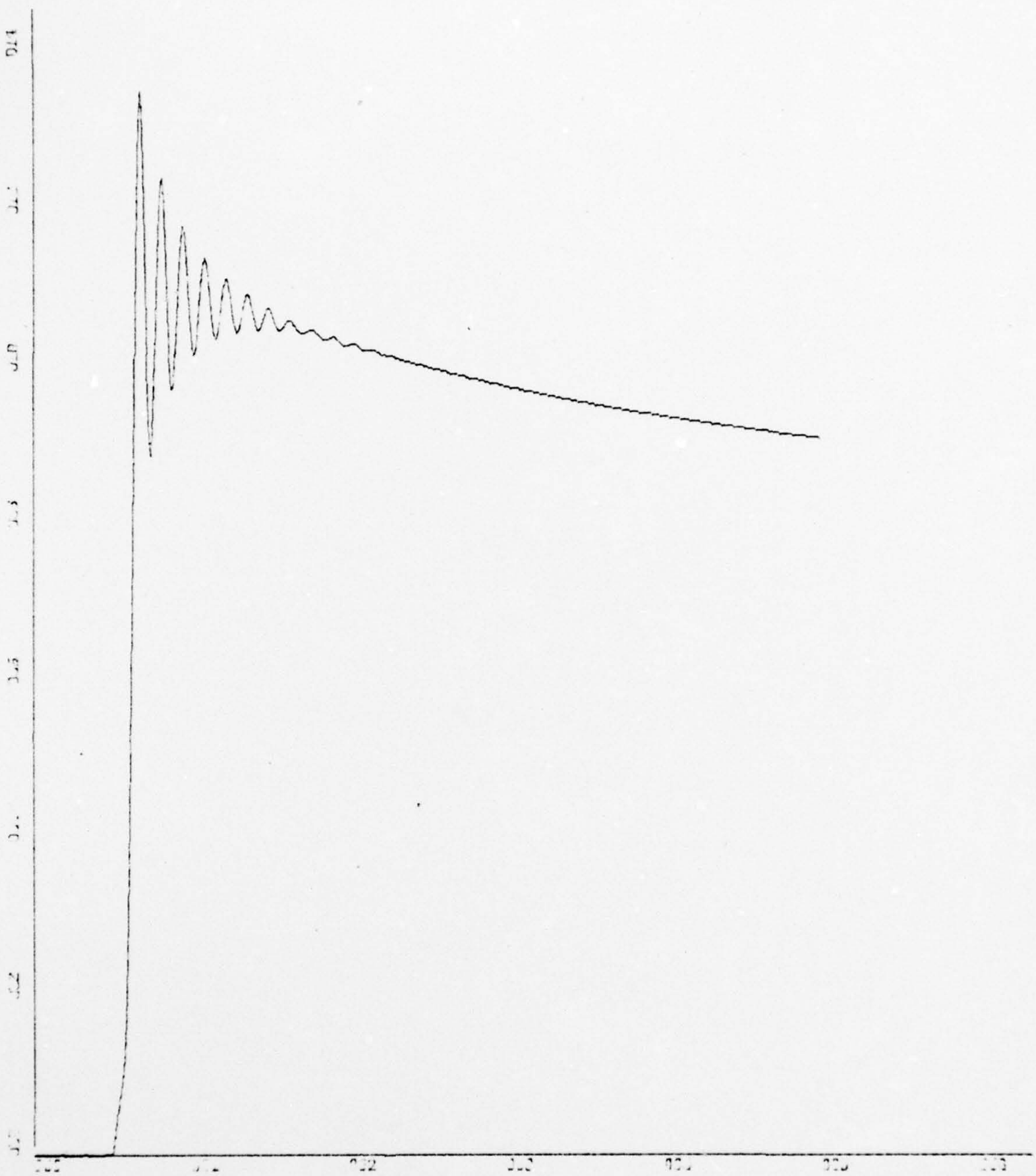
for applied parameters see first page of this appendix



X-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 5.00E-01 UNITS INCH.
RUN003 . TURN 20 KN
PLOT IS ROLL RATE VERSUS TIME

PLOT 54

for applied parameters see first page of this appendix

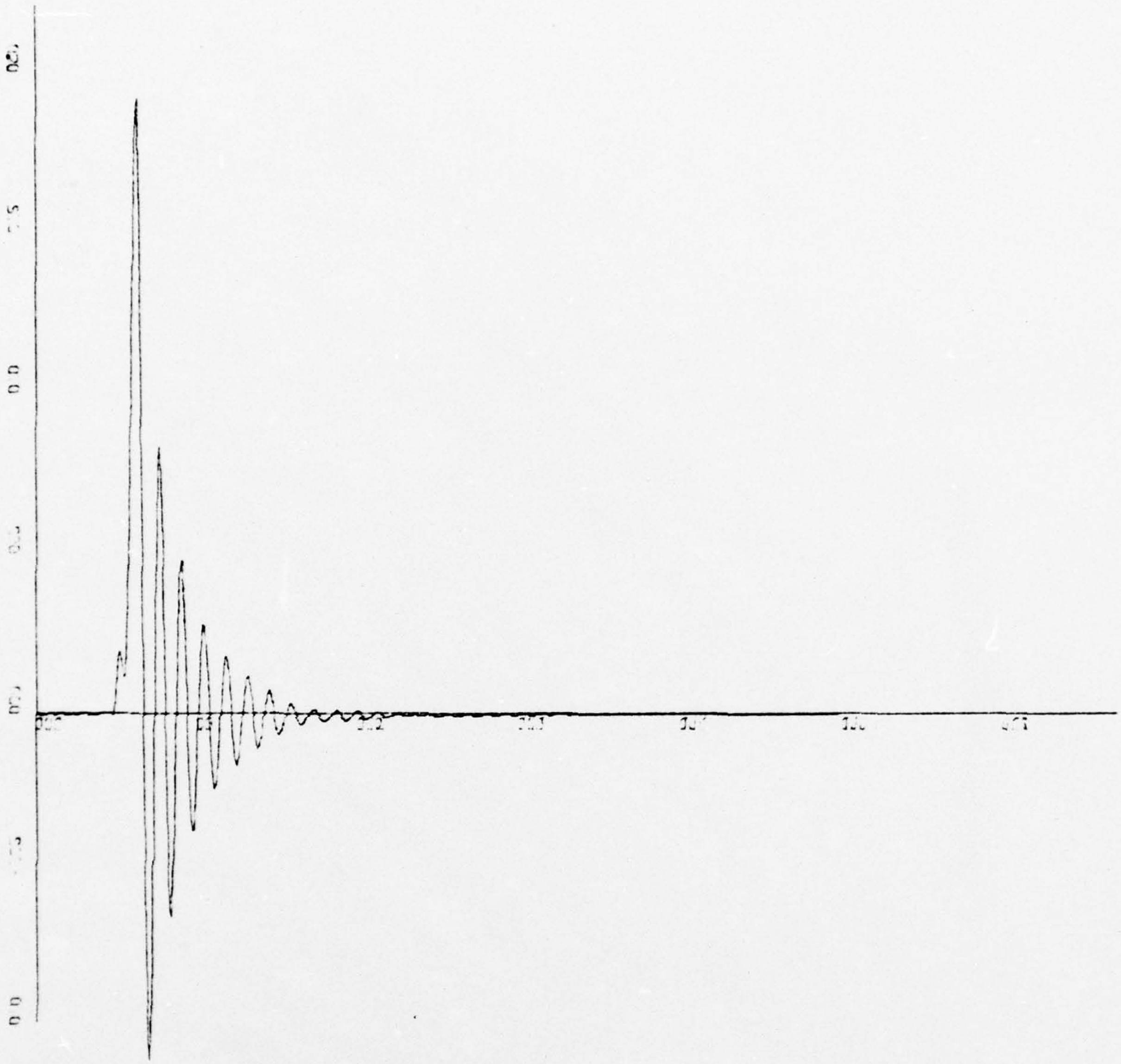


PLØT IS ROLL ANGLE VERSUS TIME

X-SCALE: 1.00E+01 UNITS INCH.
Y-SCALE: 2.00E-01 UNITS INCH.

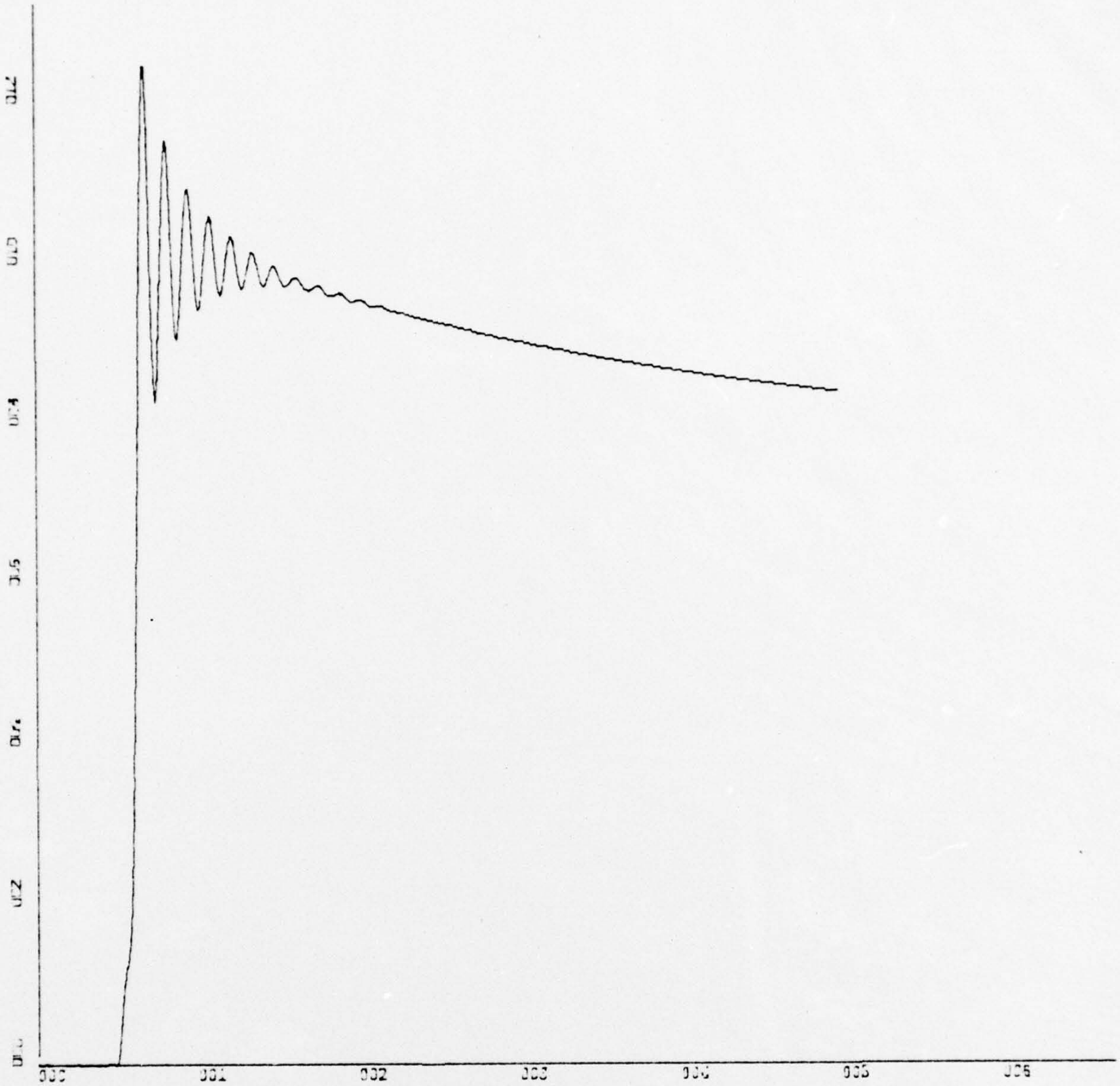
PLOT 55

for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGROF1 , TURN 20 KN , RUD=10 , NO RD
PLOT IS ROLL RATE VERSUS TIME

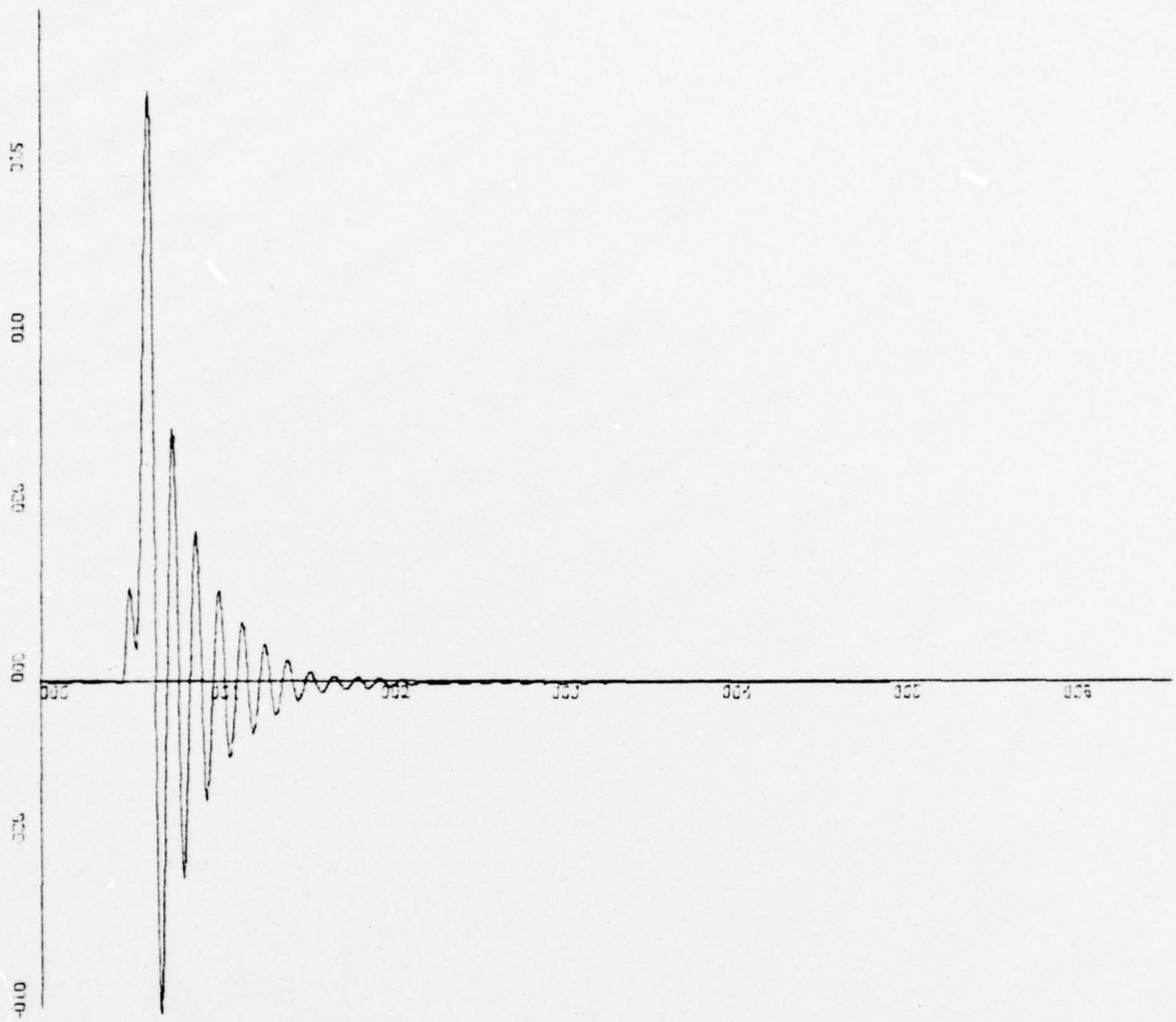
PLOT 56
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.
RGROF4 , TURN 20 KN , RUD=10 , NØ RD
PLØT IS ROLL ANGLE VERSUS TIME

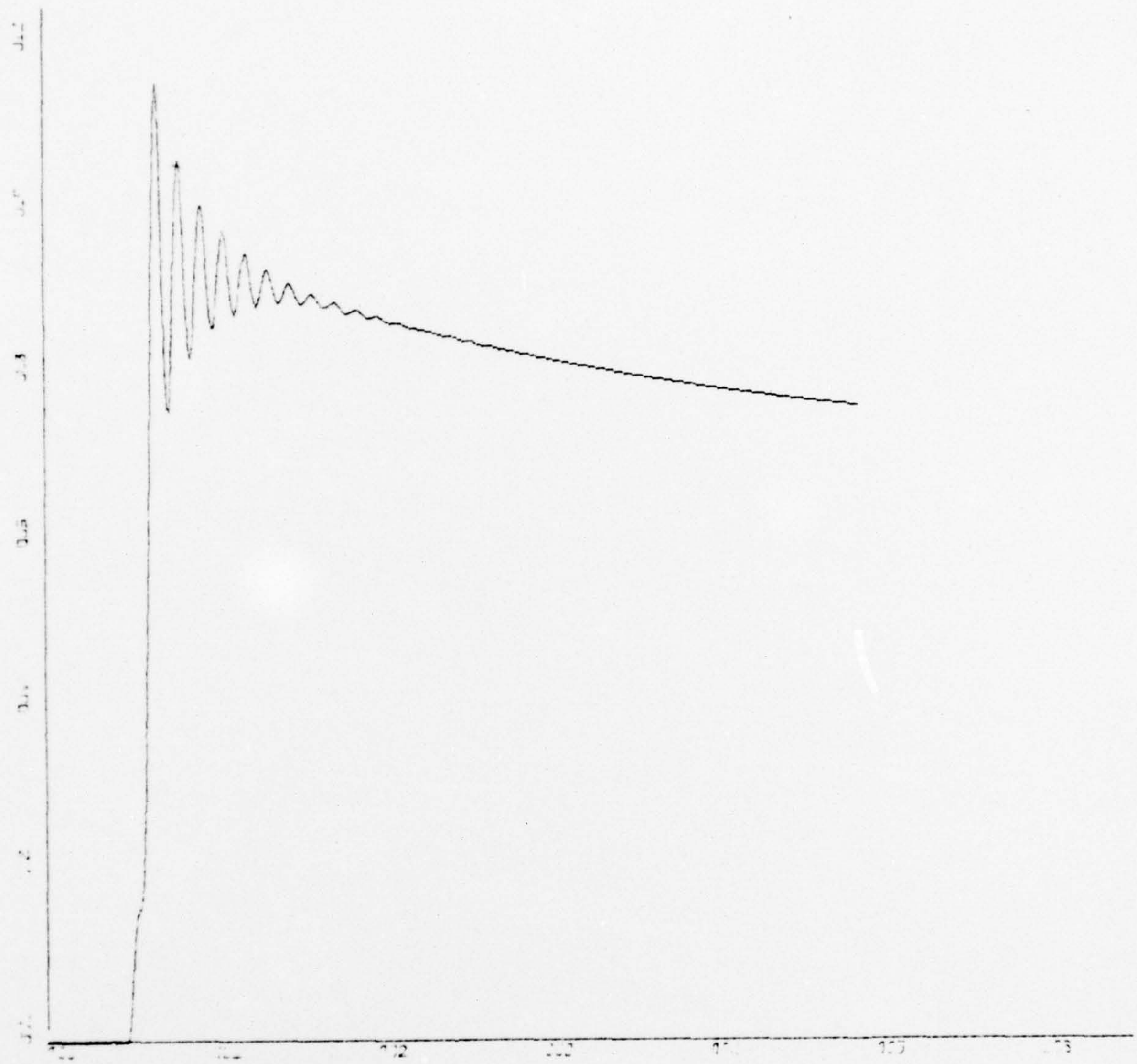
PLOT 57

for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGROF4 , TURN 20 KN , RUD=10 , NO RD
PLOT IS ROLL RATE VERSUS TIME

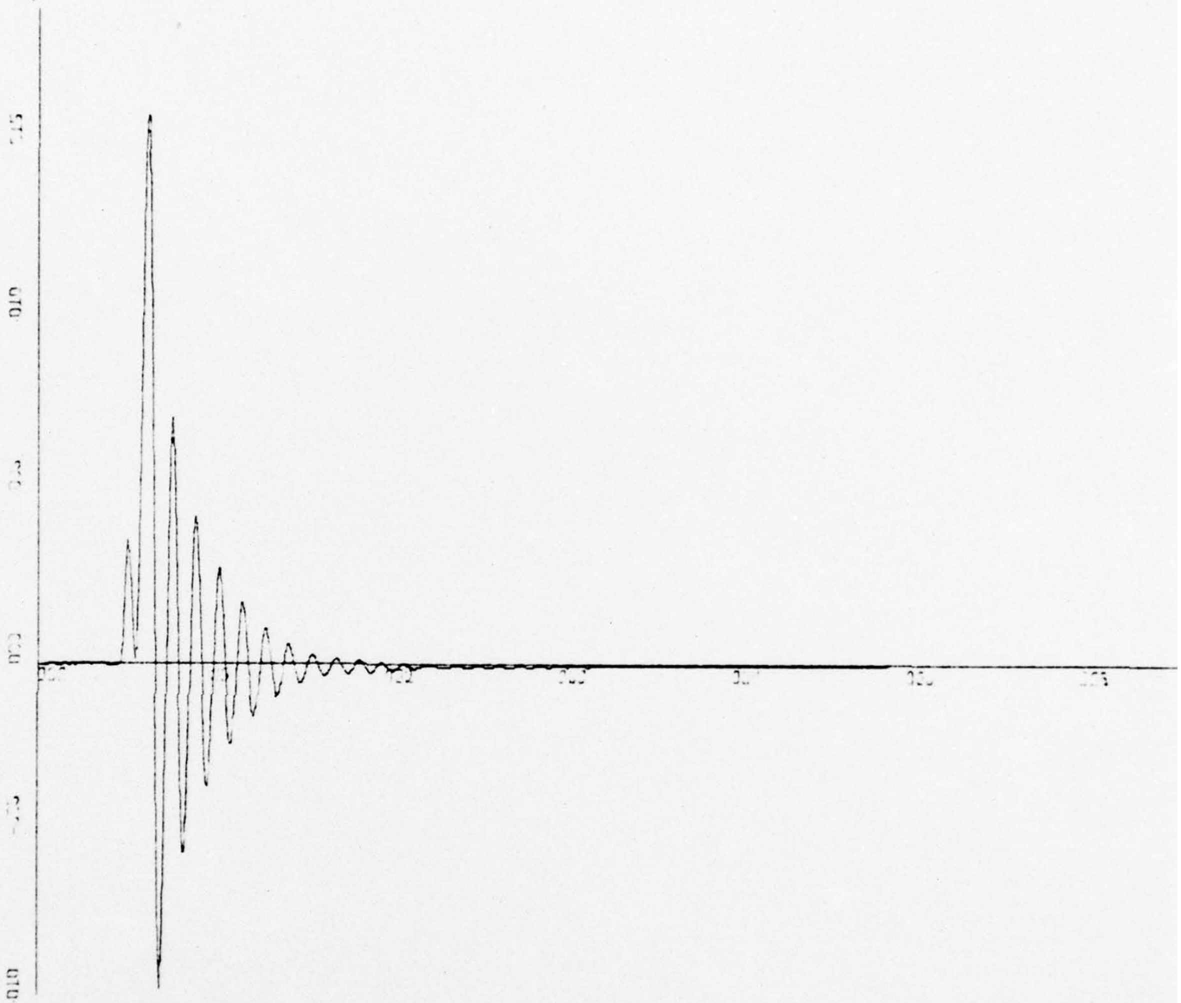
PLOT 58
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.
ACROF3 . TURN 20 KN . RUDM=15
PLØT IS ROLL ANGLE VERSUS TIME

PLOT 59

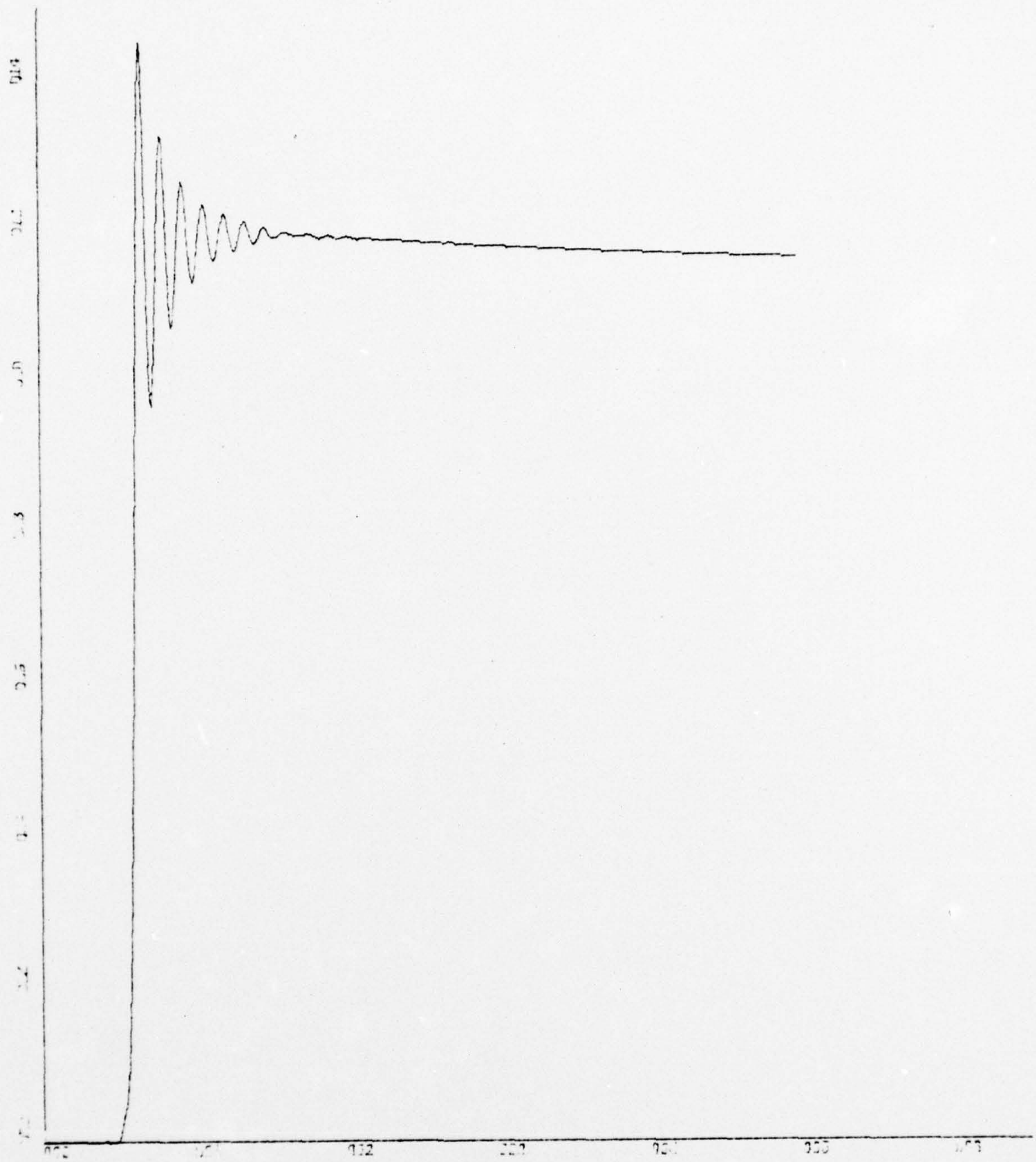
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
AGROF3 , TURN 20 KN , RUDM=15
PLOT IS ROLL RATE VERSUS TIME

PLOT 60

for applied parameters see first page of this appendix

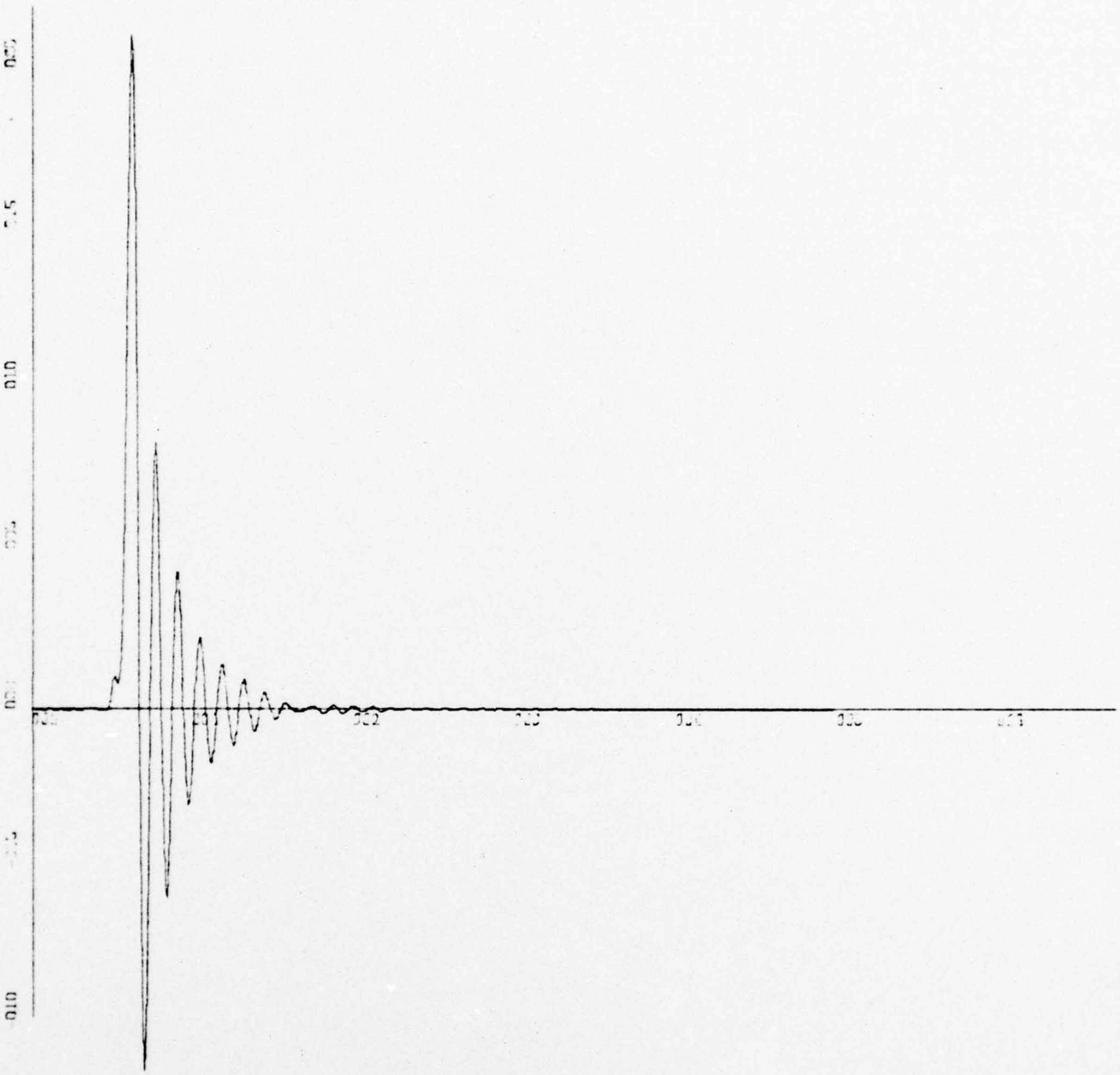


PLØT IS ROLL ANGLE VERSUS TIME

X-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 2.00E-01 UNITS INCH.

PLOT 61

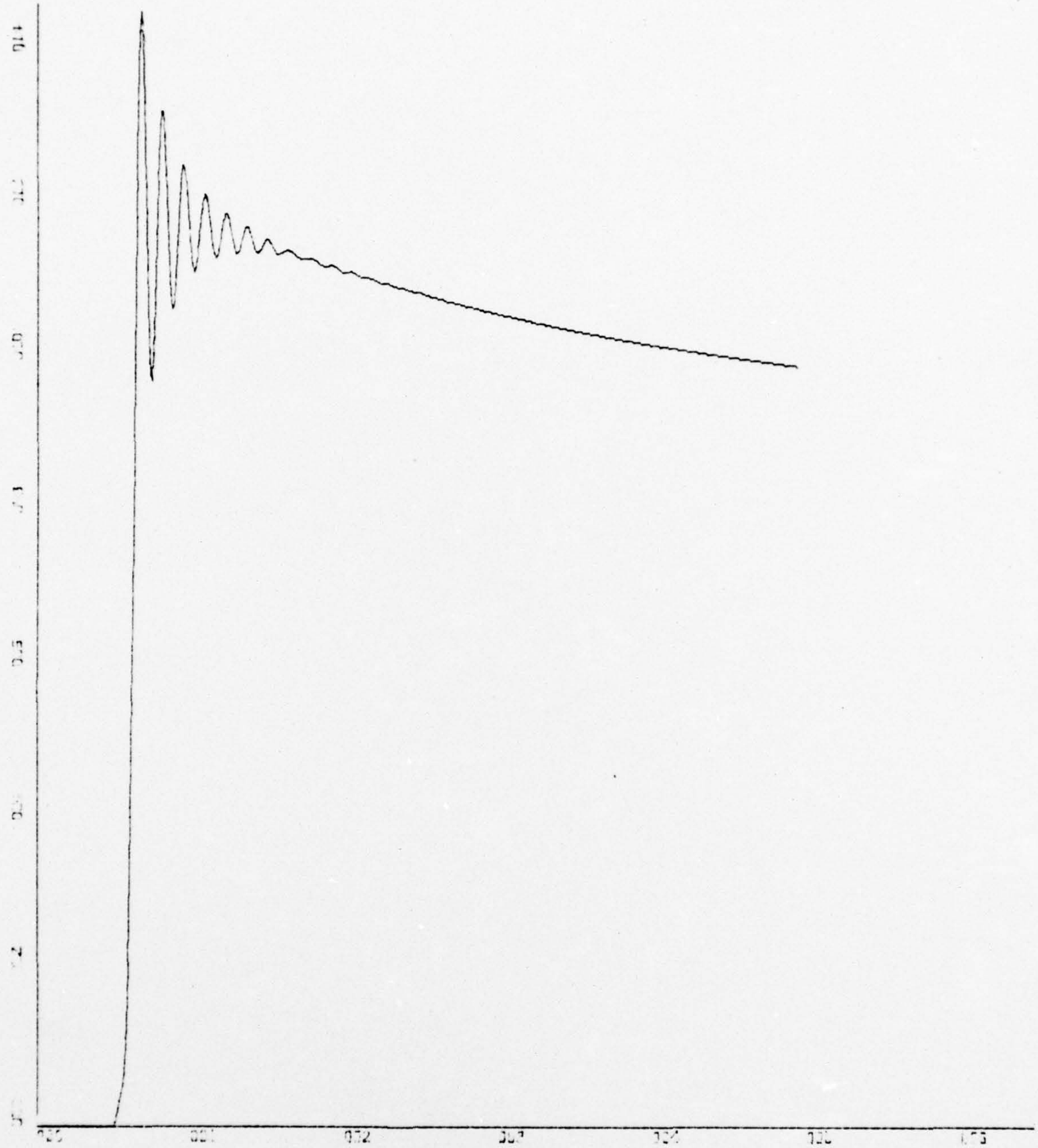
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RCROE6 , TURN 20 KN , RUD=15 , NO RD
PLOT IS ROLL RATE VERSUS TIME

PLOT 62

for applied parameters see first page of this appendix

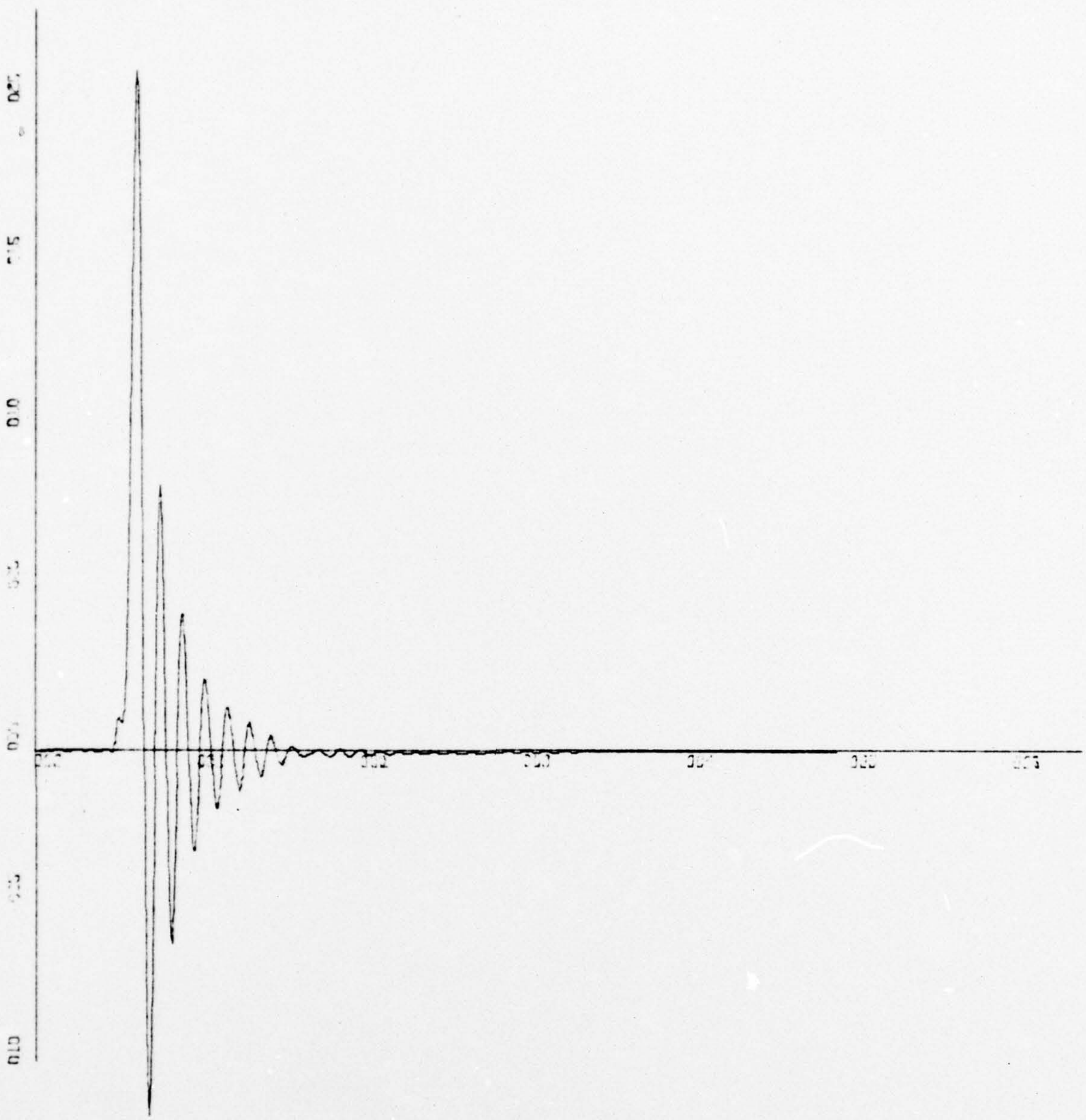


PLØT IS ROLL ANGLE VERSUS TIME

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.

PLOT 63

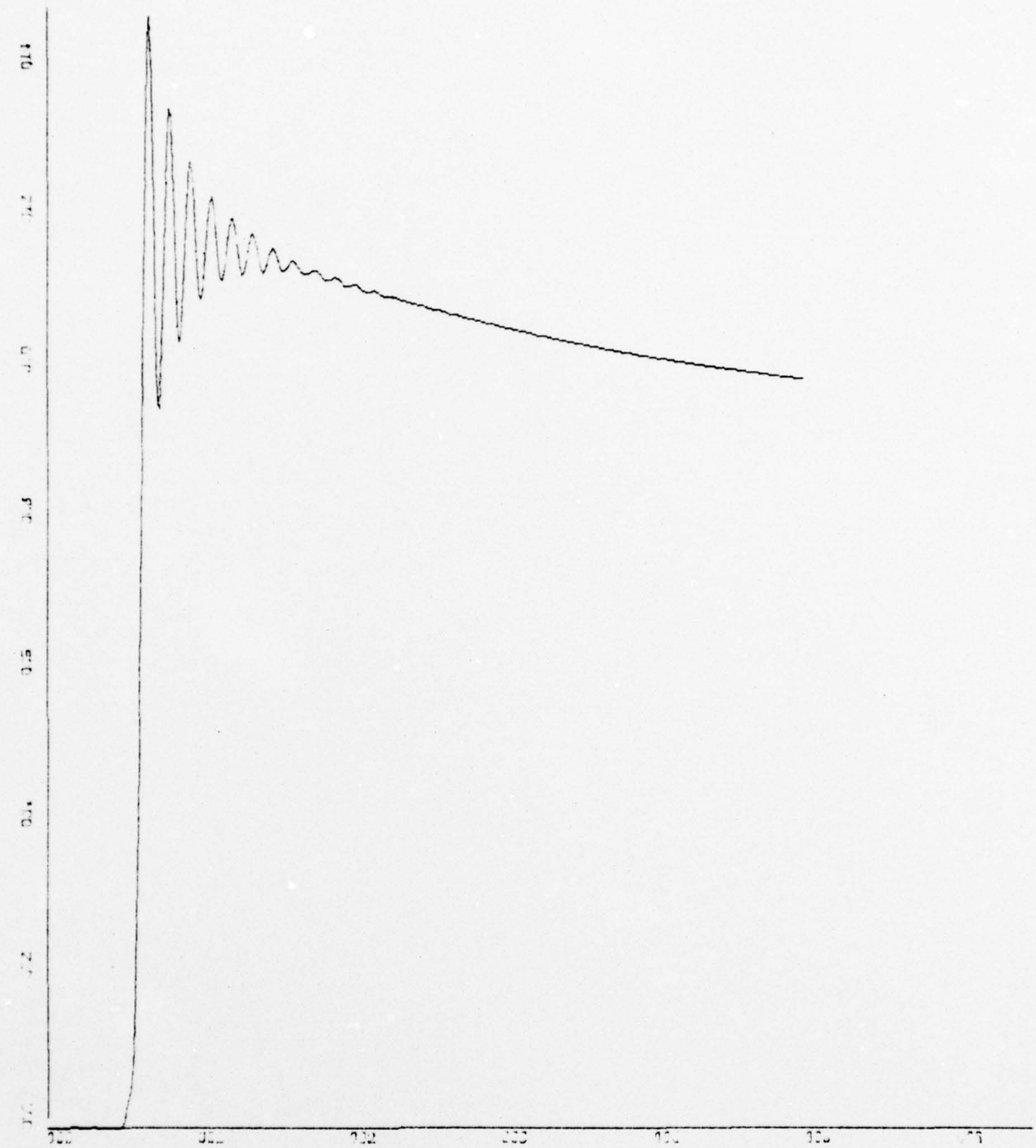
for applied parameters see first page of this appendix



X-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 5.00E-01 UNITS INCH.
RGROE9 . TURN 20 KN . RUDM=15
PLOT IS ROLL RATE VERSUS TIME

PLOT 64

for applied parameters see first page of this appendix

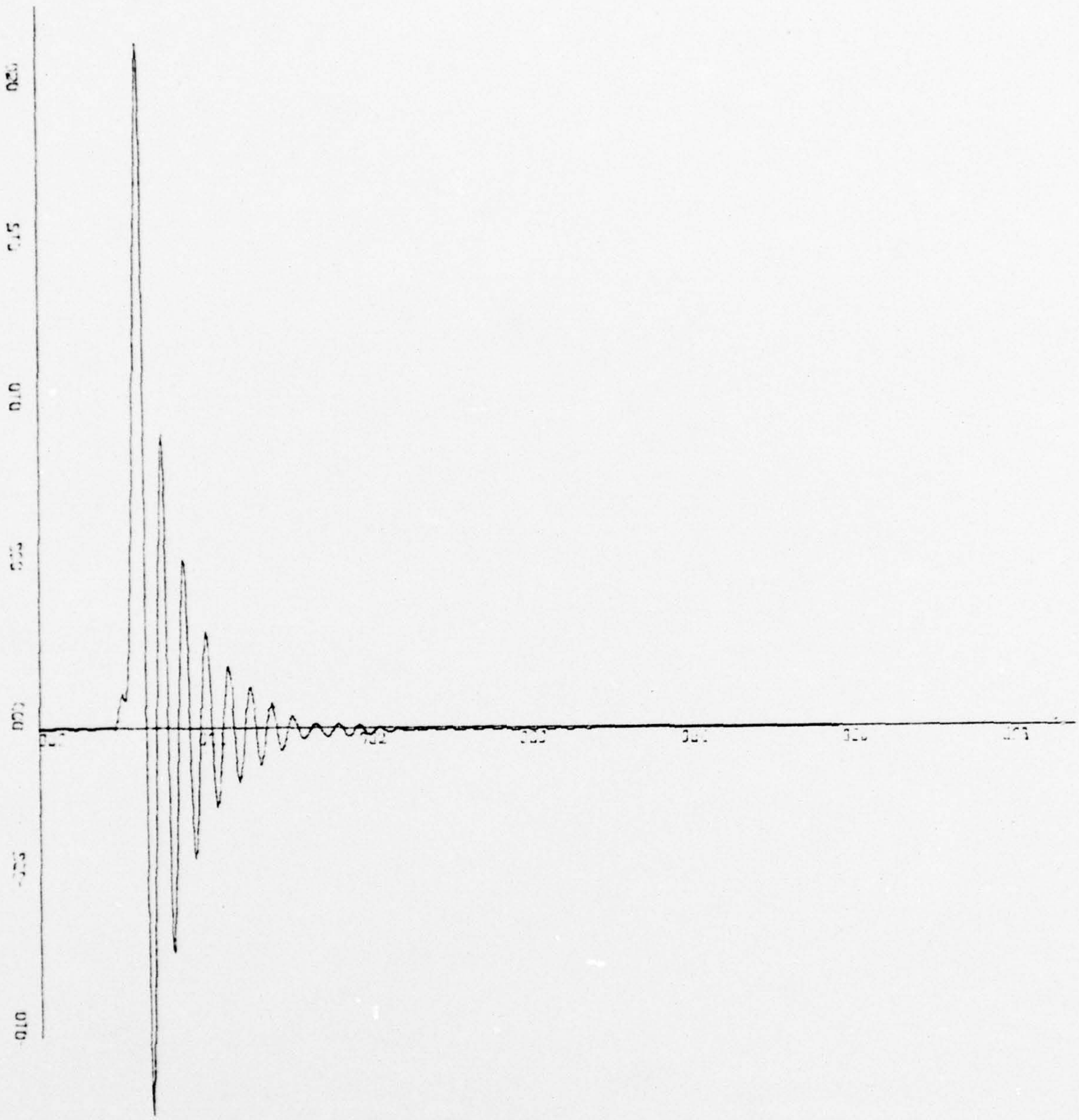


PLØT IS ROLL ANGLE VERSUS TIME

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.

PLOT 65

for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGRPE9 , TURN 20 KN , RUD=15
PLOT IS ROLL RATE VERSUS TIME

PLOT 66

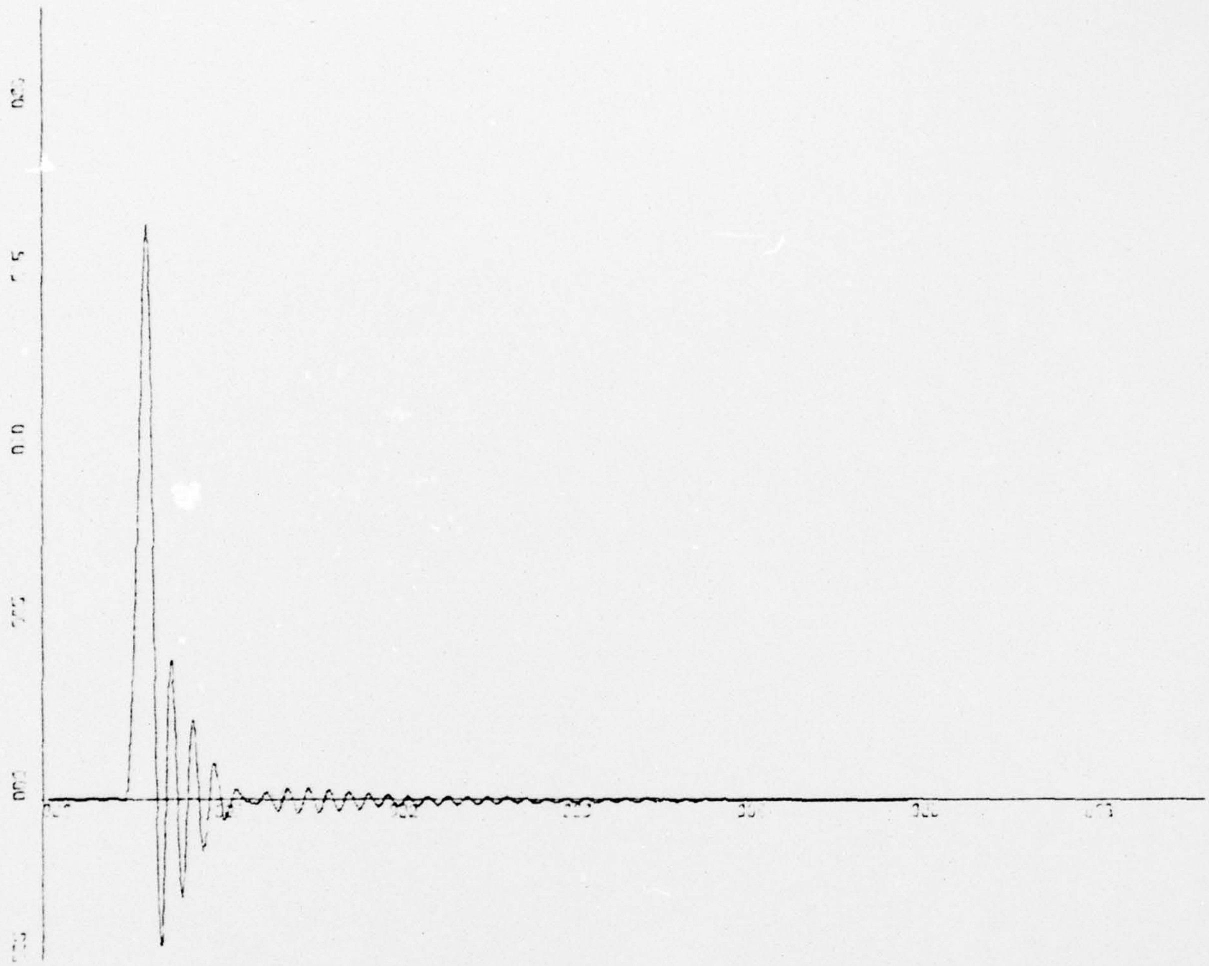
for applied parameters see first page of this appendix

PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.

PLOT 67

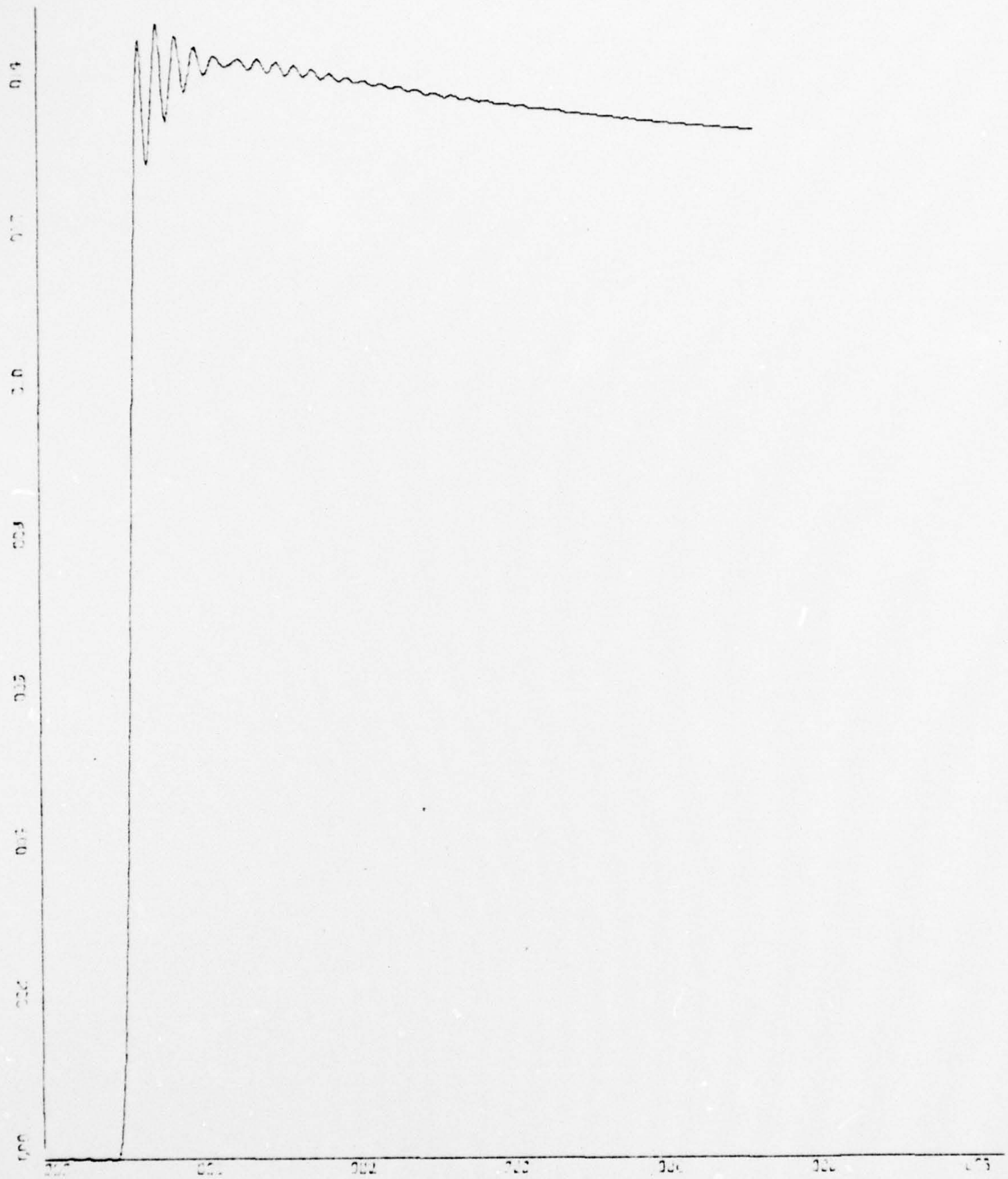
for applied parameters see first page of this appendix



X-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 5.00E-01 UNITS INCH.
AGROEB . TURN 20 KN , RUD=15 , NO RD
PLOT IS ROLL RATE VERSUS TIME

PLOT 68

for applied parameters see first page of this appendix

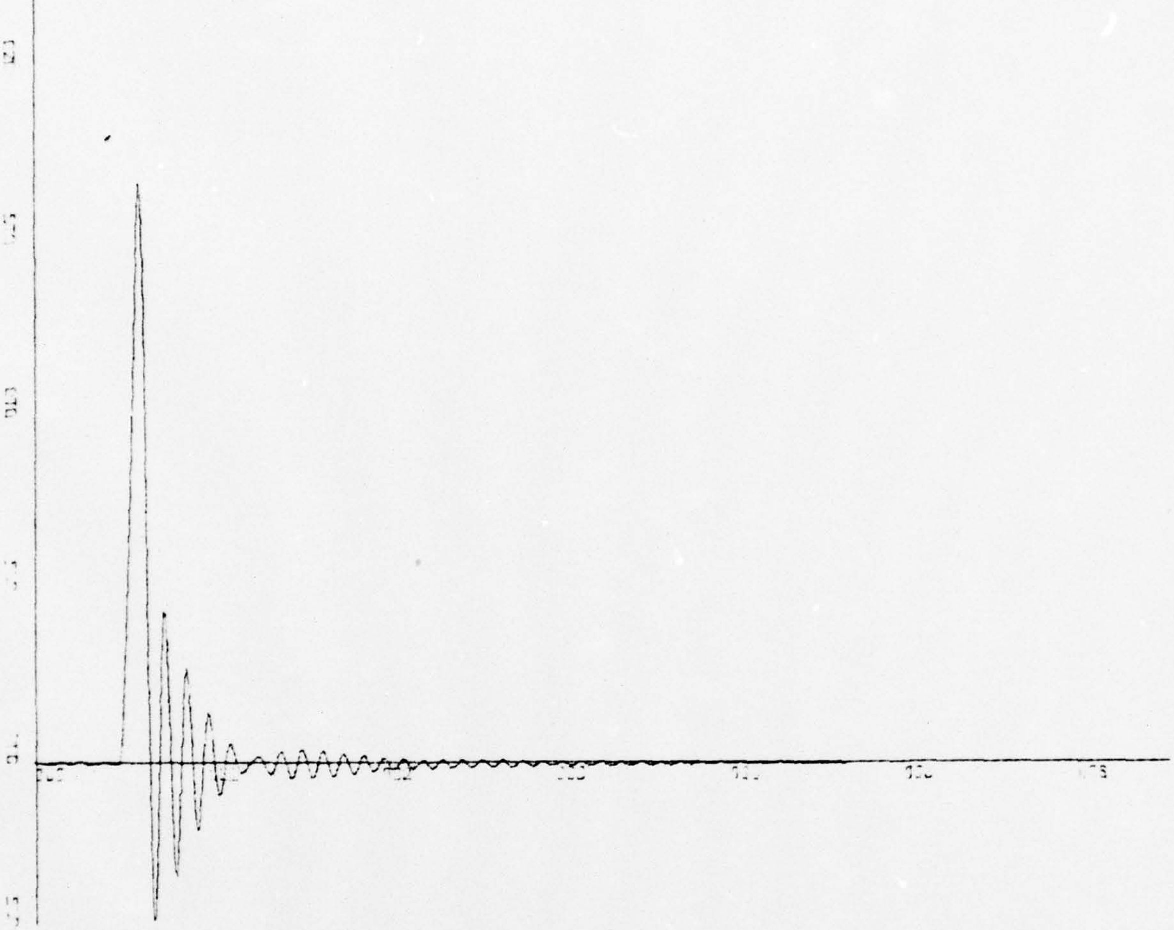


PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 2.00E-01 UNITS INCH.

PLOT 69

for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
AGRPE8 , TURN 20 KN , RUD=15
PLØT IS RØLL RATE VERSUS TIME

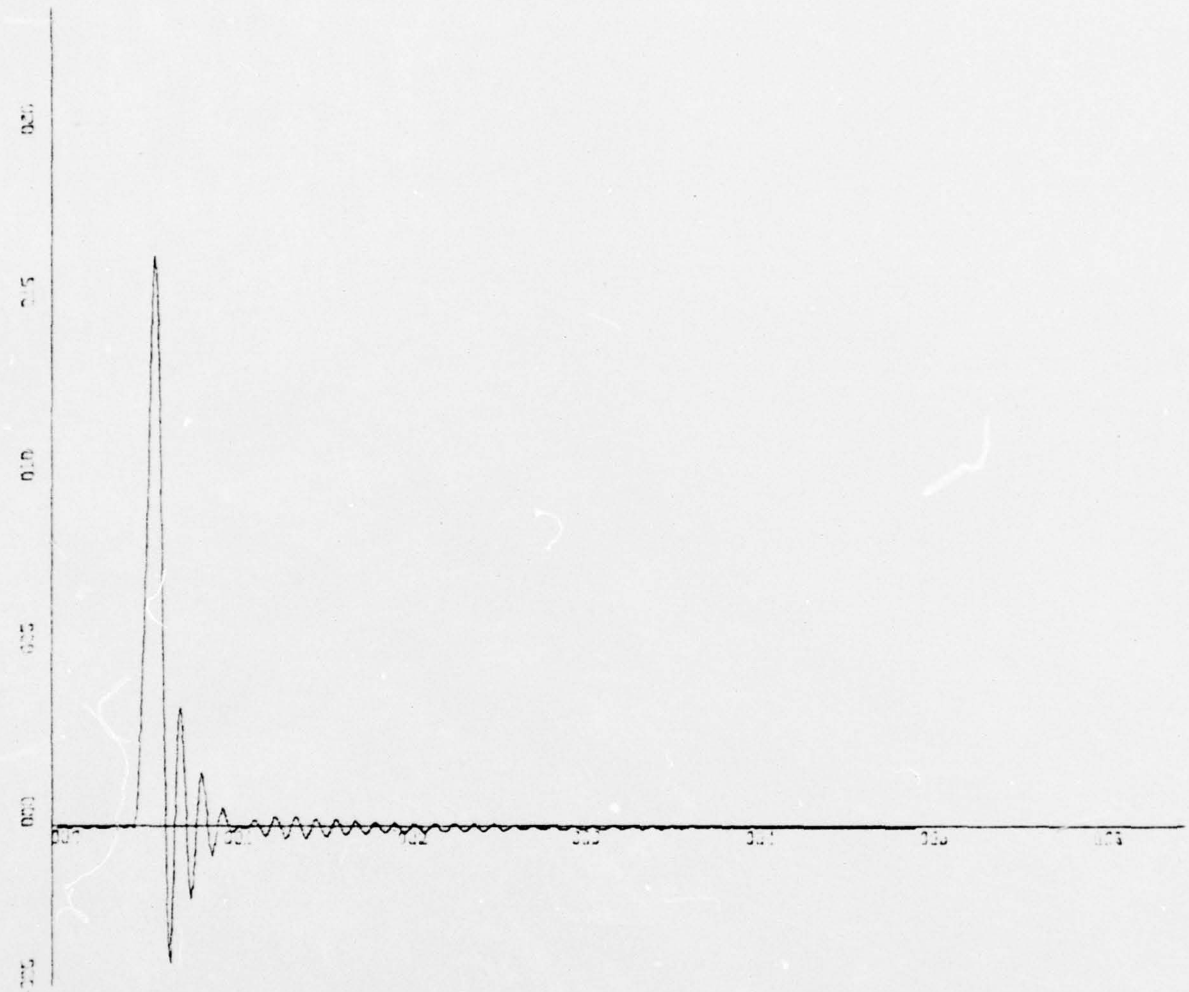
PLOT 70
for applied parameters see first page of this appendix

PLØT IS ROLL ANGLE VERSUS TIME

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.

PLOT 71

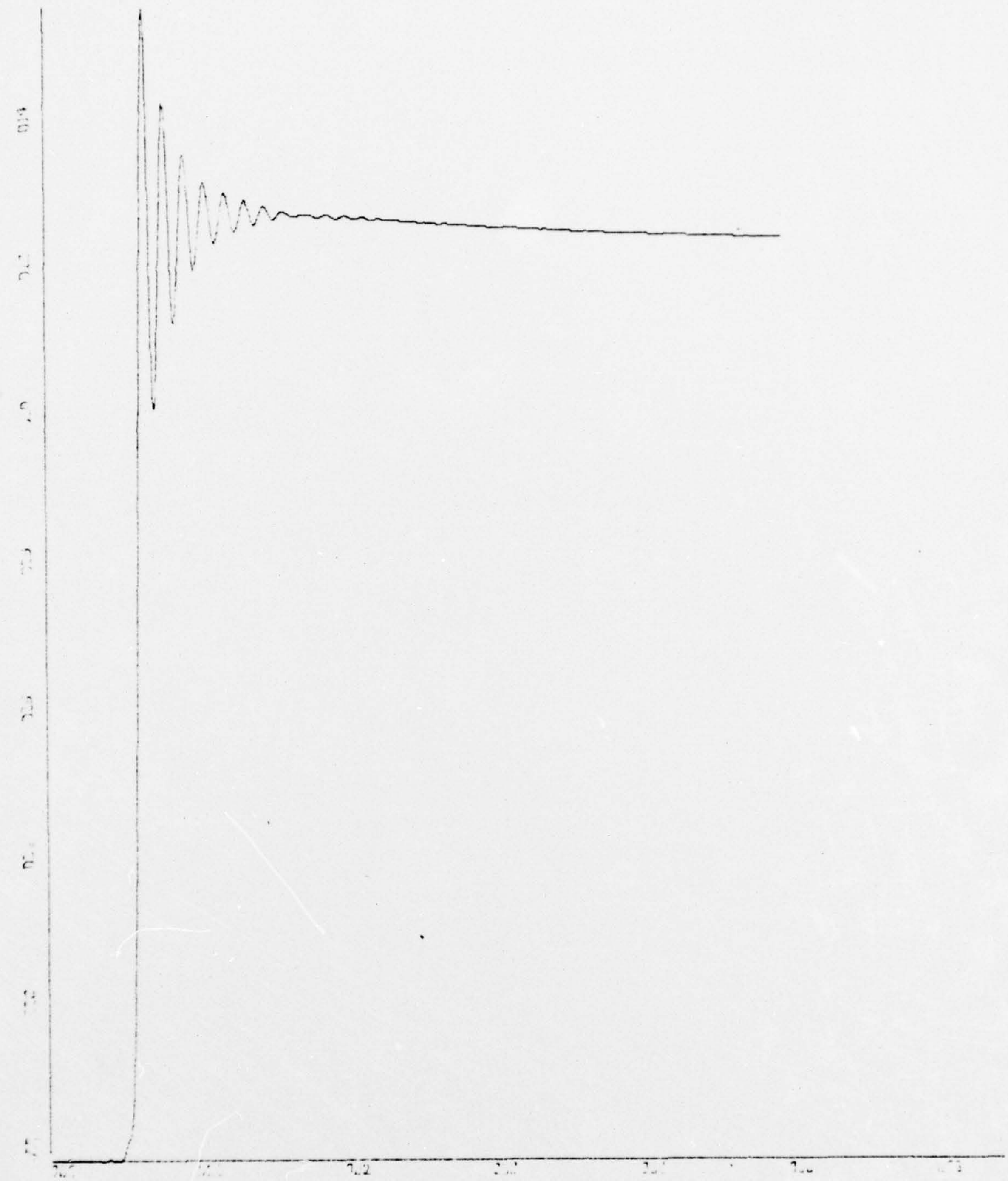
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGRPI8 , TURN 20 KN , RUD=15
PLOT IS ROLL RATE VERSUS TIME

PLOT 72

for applied parameters see first page of this appendix

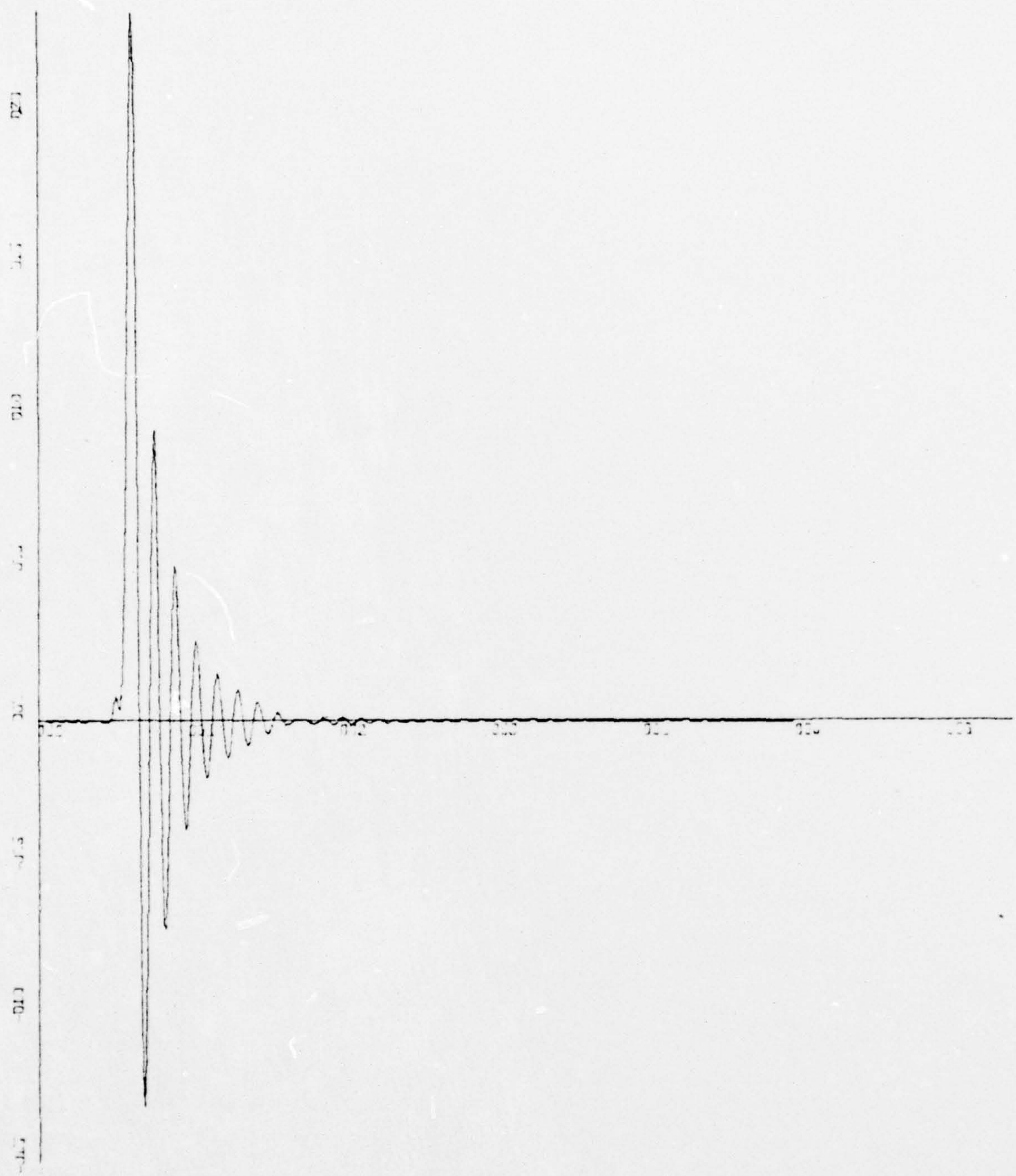


PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 2.00E-01 UNITS INCH.

PLOT 73

for applied parameters see first page of this appendix

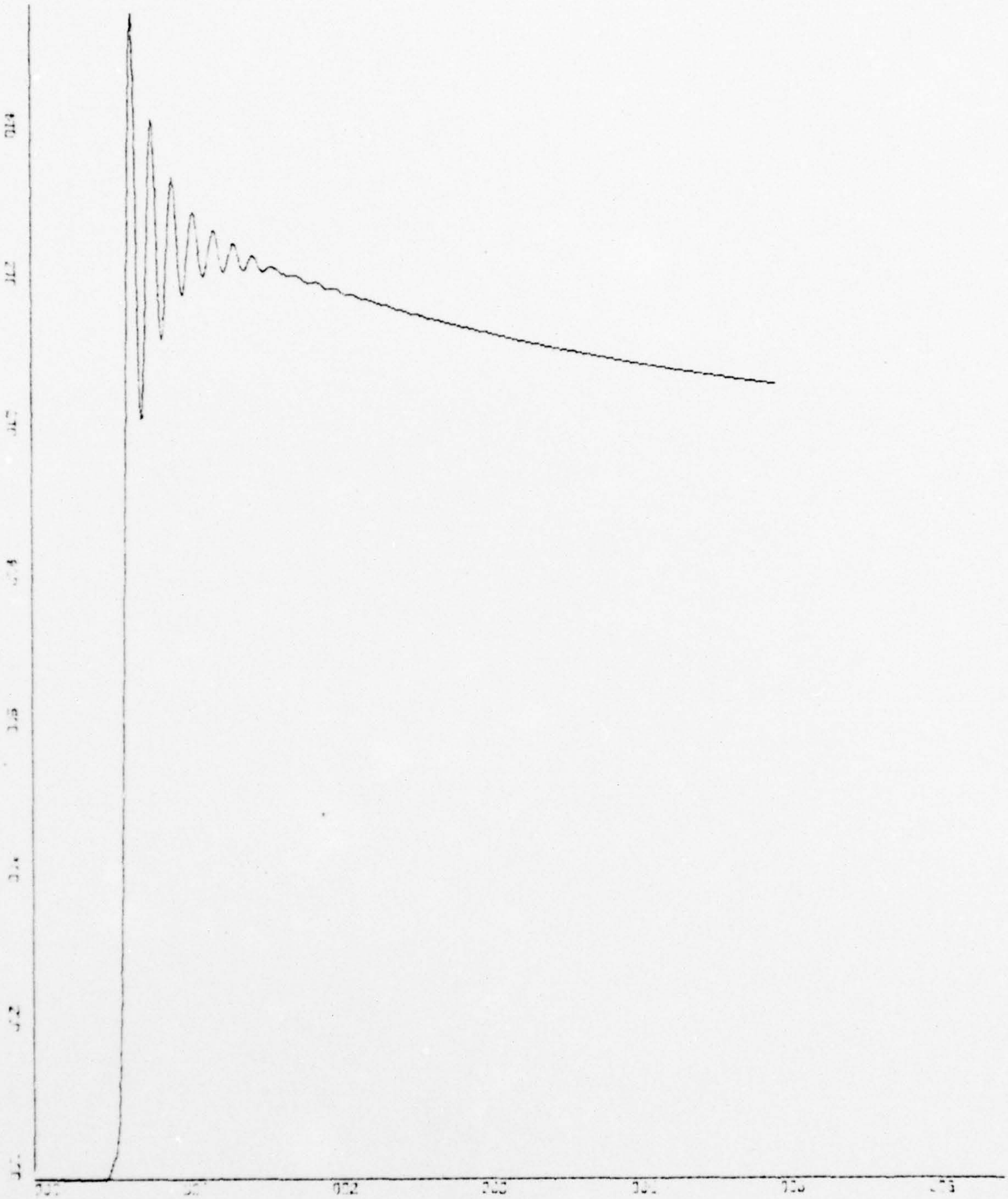


PLØT IS RØLL RATE VERSUS TIME

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.

PLOT 74

for applied parameters see first page of this appendix

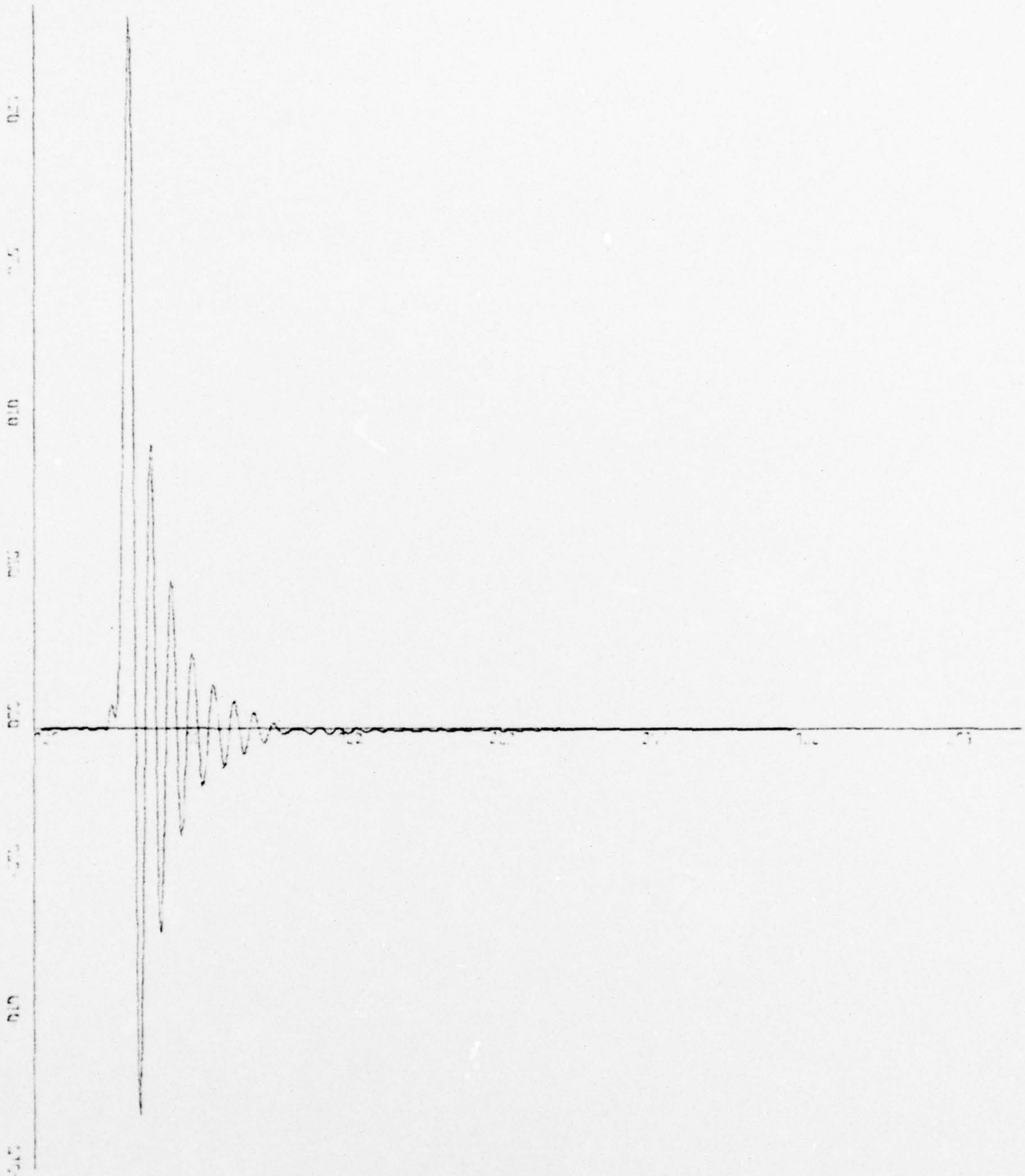


PLOT IS ROLL ANGLE VERSUS TIME

X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.

PLOT 75

for applied parameters see first page of this appendix

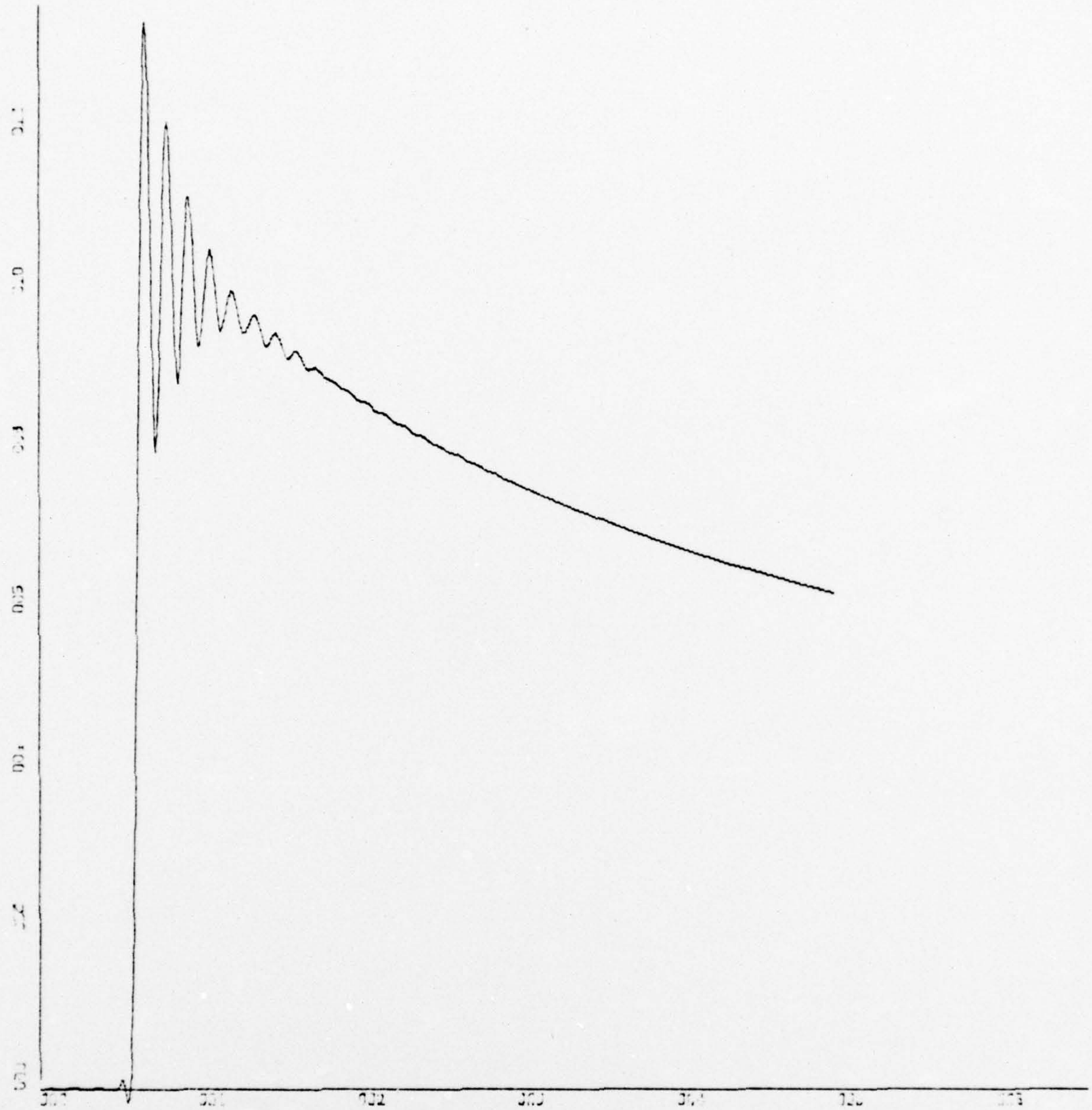


PLOT IS ROLL RATE VERSUS TIME

X-SCALE= 1.00E+01 UNITS INCH.
Y-SCALE= 3.00E-01 UNITS INCH.

PLOT 76

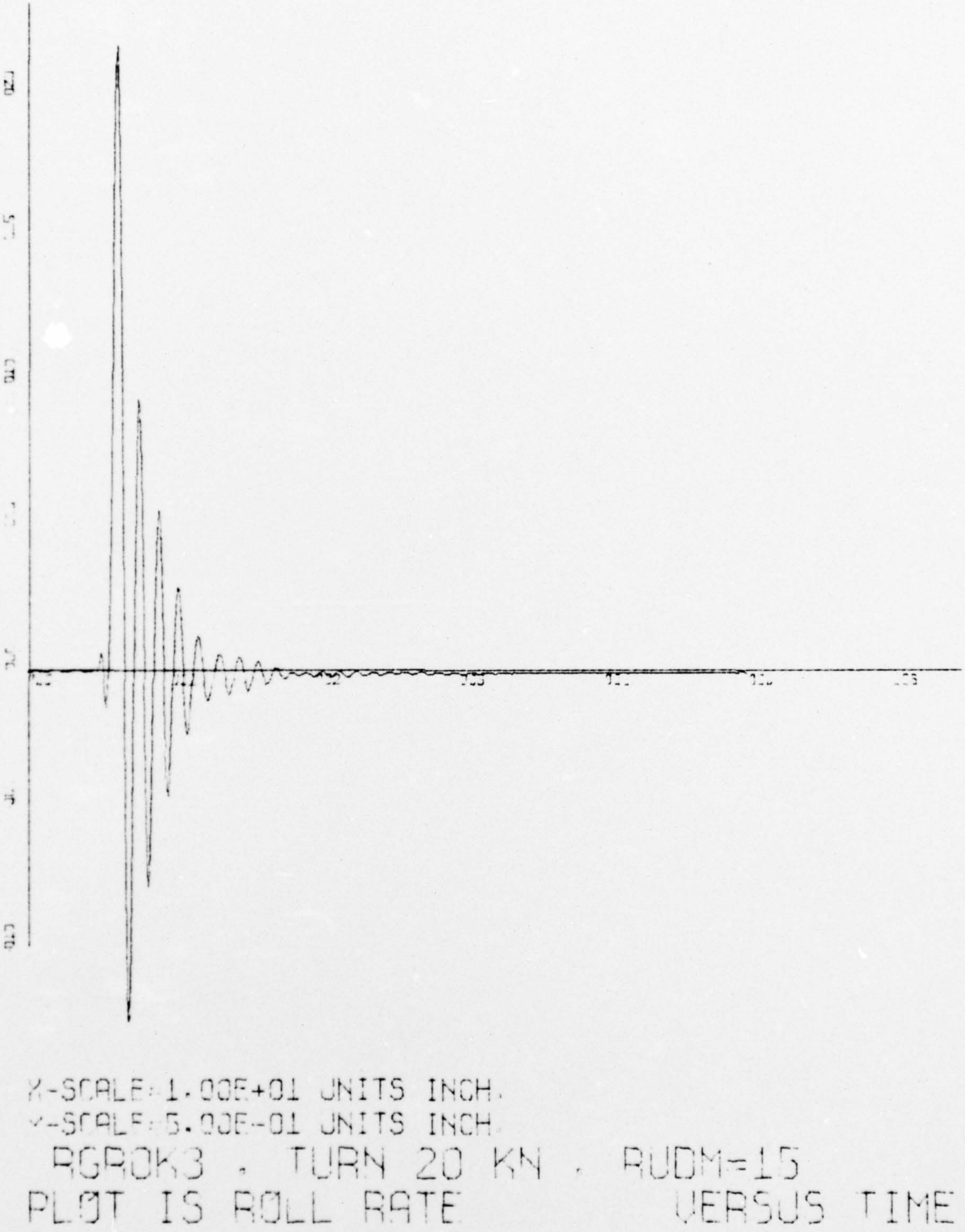
for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=2.00E-01 UNITS INCH.
RGROK3 , TURN 20 KN , RUDM=15
PLOT IS ROLL ANGLE VERSUS TIME

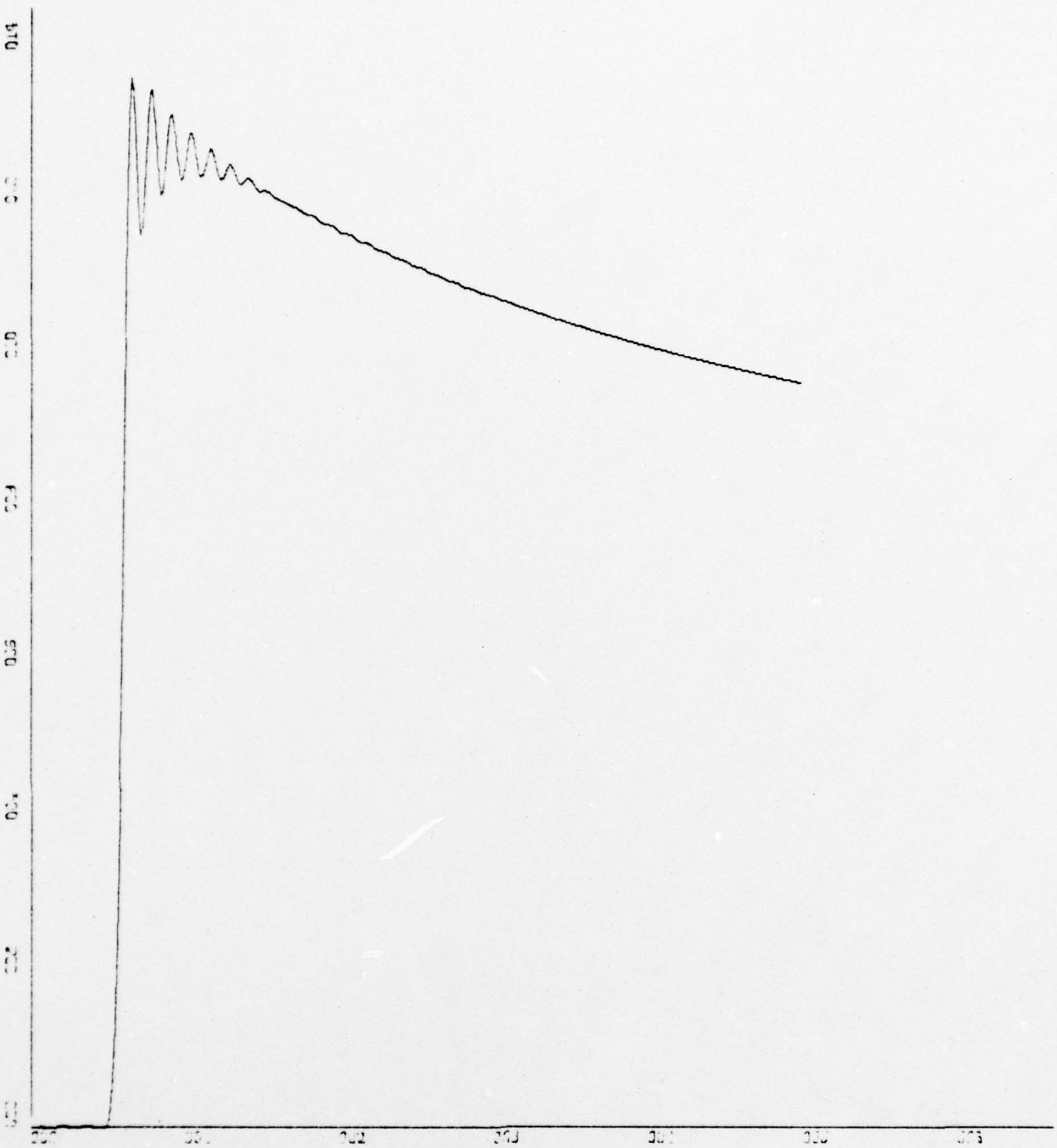
PLOT 77

for applied parameters see first page of this appendix



PLOT 78

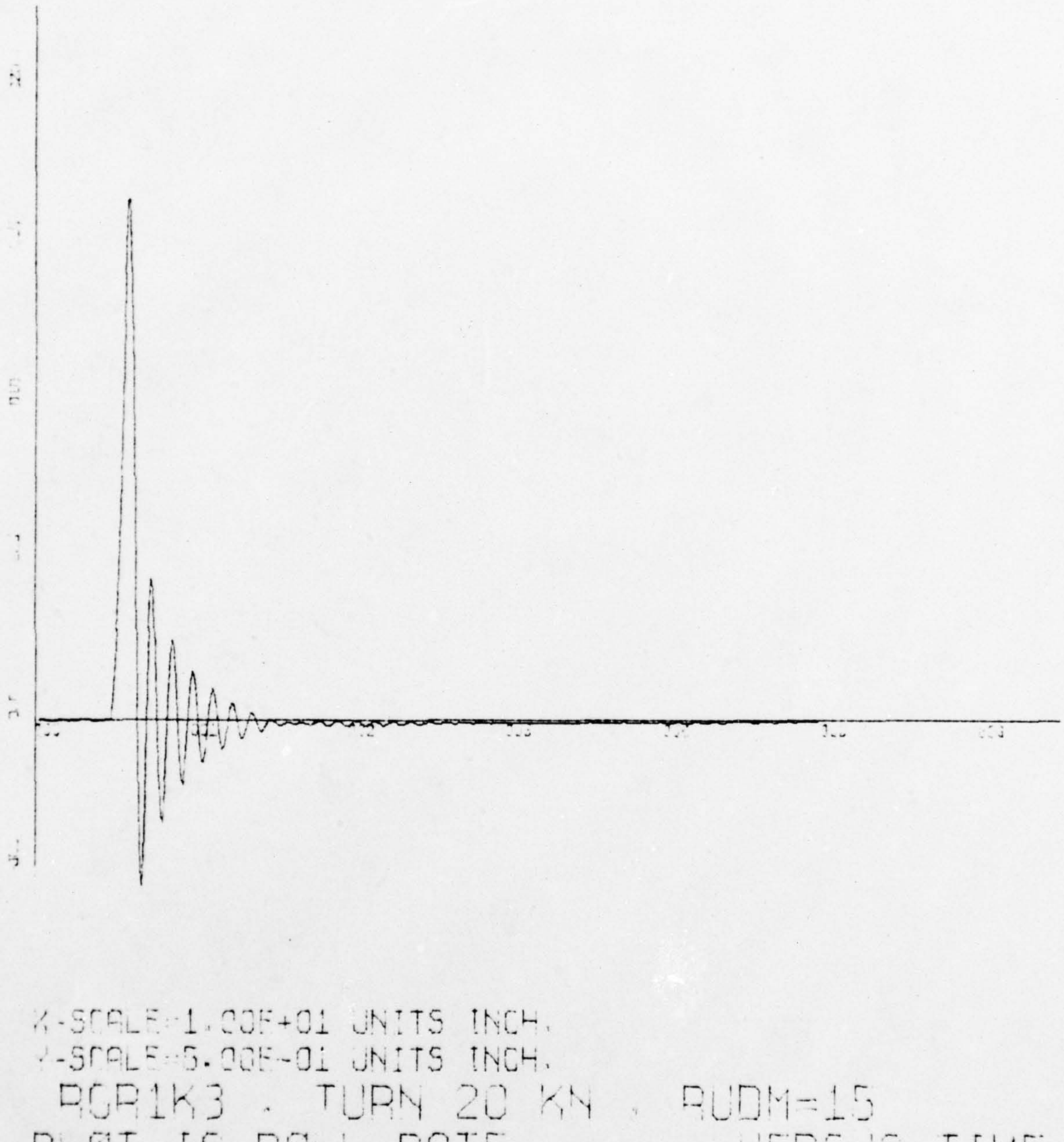
for applied parameters see first page of this appendix



X-SCALE 1.00E+01 UNITS INCH.
Y-SCALE 2.00E-01 UNITS INCH.
RGR1K3 . TURN 20 KN . RUDM=15
PLOT IS ROLL ANGLE VERSUS TIME

PLOT 79

for applied parameters see first page of this appendix



X-SCALE=1.00E+01 UNITS INCH.
Y-SCALE=5.00E-01 UNITS INCH.
RGR1K3 . TURN 20 KN . RUDM=15
PLOT IS ROLL RATE VERSUS TIME

PLOT 80
for applied parameters see first page of this appendix

APPENDIX B

MODIFICATIONS OF THE SIMULATION PROGRAM

During the course of studies undertaken with the XR-3 Loads and Motion Program some statements have been added or changed in order to improve the work with the simulation program.

* MAIN program

The statements

```
COMMON /AIR/ PINF,RHOINF,GAM,IQUIT         (MAIN0050)
IF (MYTIME(DUM).LT.IQUIT) GO TO 12         (MAIN0661)
```

have been modified and added to the MAIN-program. The purpose of the second statement is to start the writing of the output values desired if computer time has reached the demanded time (jobcard) reduced by IQUIT which is the expected amount of time (in 10 * seconds) required to print the output. The user may input the desired value of IQUIT as the fourth parameter (I10-Format, columns 36-45) on the 107 data card. Default value for IQUIT is 600000 (60 seconds).

* Subroutine INCON

The added statements are

```
IQUIT=600000                               (INCN0881)
```

to set the default value and

```
READ (5,2041) IQUIT                        (INCN1455)
```

to read the set value for IQUIT thereby overriding the default value.

* Subroutine RHS

In Menzel's version [Ref. 2] of the XR-3 Loads and Motions Program the entered craft's velocity UO (kn) is changed in Subroutine INCON to U (ft/sec) by

```
        U = UO*1.6889                          (INCN4580)
```

and in Subroutine RHS transformed back to units in knots (RHS 1850) by

```
        VEL = 0.5925*U .                       (RHS 1850)
```

From these two equations follows

```
        VEL = 0.5925*UO*1.6889
```

and for UO=20 kn there results VEL = 20.0135 kn . But since it is desired that VEL=UO the statement has been corrected to

```
        VEL = U/1.6889 .
```

Statements MAIN0840, RHS 1140 have been changed accordingly.

* Subroutine INTGRL

To this subroutine the statement

```
        CALL COLFIL                            (INT 1021)
```

has been added in order to provide the output values already calculated to the user if the minimum time interval allowed in the integration process is undergone. Before this addition only the warning message

'DELTA TIME LESS THAN 1.0E-6 - - JOB STOPS'

appeared and the output values have been lost.

APPENDIX C

XR-3 LOADS AND MOTIONS PROGRAM

```
C
C     MAIN DECK
C
      INTEGER ON
      COMMON /AIR/ PINF,RHOINF,GAM,IQUIT
      COMMON /BMCO / IMM,IMNX,IMNY,IBMFIL,BTIME,INT,XMI(10),YMI(7),IX,IY
      COMMON /CONST/ PI,RAD,U0
      COMMON/ENGINE/NPS,NPP,THSTS(25),THSTP(25),XP,YP,ZP,STHS,STHP,
     ATIP(25),TIS(25)
      COMMON /EQNCO/ NECS,TCL(20),JQQ
      COMMON /FPROP/ FXP,FYP,FZP,FKP,FMF,FNP
      COMMON / FROUDE / FN,FNCRIT
      COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7
      COMMON /PRTINT/ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,
     -IRLD,IPROP,IAEROD,IRHS
      COMMON /ROLL/ PHIMAX,TROLL
      COMMON/RUDDR/ NPR,DELRUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR,
     ARCLB,RTC,RUDANG,TIR(25)
      COMMON / VALOLD / YOLD(20)
      COMMON /VARBLE/ VAL(40)
      COMMON /WAVE/ ETA(4,11),AW(10),OMEGA(10),CVCLW,NWAVE,BETA,
     1              FXWAV,FYWAV,FZWAV,FKWAV,FMWAV,FNWAV
     2              ,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBBAR
      EQUIVALENCE            (VAL(2),U),(VAL(3),V),(VAL(4),W),
     1(VAL(5),P),(VAL(6),Q),(VAL(7),R),(VAL(8),PHI),(VAL(9),THETA),
     2(VAL(10),Z),(VAL(11),BMASS),(VAL(21),X),(VAL(22),Y),(VAL(23),PSI),
     3(VAL(24),PB)
      DIMENSION DUMMY(20)
C
      TC=1.0
      CN=1
      PI=4.*ATAN(1.)
      RAD=180./PI
      WRITE(6,100)
  100 FORMAT(1H1//35X,22H LISTING OF INPUT DECK  //)
   99 READ(44,101,END=104) DUMMY
  101 FORMAT(20A4)
  105 WRITE(6,102)DUMMY
      WRITE(5,101) DUMMY
  102 FORMAT(5X,20A4)
      GO TO 99
  104 REWIND 5
C
   11 CALL INCON(TIME)
C
      IF (IMM.EQ.3)  GO TO 605
      DO 10 J=1,20
```

```
 10   YOLD(J)=VAL(J+1)                                                   MAIN0490
      GO TO 2                                                            MAIN0500
  1   CONTINUE                                                           MAIN0510
      TOLD=TIME                                                          MAIN0520
      PBBAR=PBBAR*(1.-DELT/TC)+DELT*(PB-PINF)/TC                         MAIN0530
      IF ( NWAVE.LE.0 )  GO TO 13                                        MAIN0540
      ZBAR=(1.-DELT/TC)*ZBAR+DELT*Z/TC                                   MAIN0550
      PHIBAR=(1.-DELT/TC)*PHIBAR+DELT*PHI/TC                             MAIN0560
      THEBAR=(1.-DELT/TC)*THEBAR+DELT*THETA/TC                           MAIN0570
C                                                                        MAIN0580
      CALL WAVES(TIME)                                                   MAIN0590
 13   CALL SIDEWL                                                        MAIN0600
      CALL PROP                                                          MAIN0610
      CALL RUDDER                                                        MAIN0620
      CALL AEROD                                                         MAIN0630
      CALL INTGRL(TIME)                                                  MAIN0640
C                                                                        MAIN0650
      IF(TIME.GT.FTIME) GO TO 12                                         MAIN0660
      IF (MYTIME(DUM).LT.IQUIT) GO TO 12                                 MAIN0661
      IF ( FN.GT.FNCRIT) GO TO 14                                        MAIN0670
      PRINT 505                                                          MAIN0680
      GO TO 12                                                           MAIN0690
 14   DELOLD=TIME-TOLD                                                   MAIN0700
      PSI=PSI+DELOLD*R                                                   MAIN0710
      X=X+DELOLD*(U*COS(PSI)-V*SIN(PSI))                                 MAIN0720
      Y=Y+DELOLD*(U*SIN(PSI)+V*COS(PSI))                                 MAIN0730
 15   IF (ABS(TIME-TPRINT) .LT. 1.E-6) GO TO 2                           MAIN0740
      GO TO 1                                                            MAIN0750
 2    CONTINUE                                                           MAIN0760
      IF(ITRAJ .EQ. 0) GOTO 16                                           MAIN0770
      DPHI=PHI*RAD                                                       MAIN0780
      DPSI=PSI*RAD                                                       MAIN0790
      DTHETA=THETA*RAD                                                   MAIN0800
      DP=P*RAD                                                           MAIN0810
      DQ=Q*RAD                                                           MAIN0820
      DR=R*RAD                                                           MAIN0830
      VEL=0.5925*U                                                       MAIN0840
      WRITE (6,500) TIME,VEL,V,W,DP,DQ,DR,Z,DPHI,DTHETA,X,Y,DPSI         MAIN0850
      BETS=(-V/U)*RAD                                                    MAIN0860
      DELRS=RUDANG*RAD                                                   MAIN0870
      WRITE(6,501) BETS,DELRS,FXP                                        MAIN0880
16    CONTINUE                                                           MAIN0890
      IMMTAG = (IMM+1)/2                                                 MAIN0900
      IF ( IMMTAG .EQ. 1  .AND. TIME.GE.BTIME-1.E-8 )  IMT = 1           MAIN0910
      TPRINT=TPRINT+DELPNT                                               MAIN0920
      CN=1                                                               MAIN0930
      GO TO 1                                                            MAIN0940
C                                                                        MAIN0950
```

```
   12  CALL COLFIL
C
       IF (IMM.LT.1)  GO TO 11
       IF (IMM.NE.1)  GO TO 605
       END FILE IBMFIL
       GO TO 11
C
  605 CALL SAM
C
       GO TO 11
C
  500 FORMAT(//10X,13HTIME (SEC) =  F6.2//10X,33HTRANSLATIONAL VELS (KTS
     1)/(FT/SEC) /10X,2HU= F6.2,5X,2HV= F6.2,5X,2HW= F6.3//10X,31HROTATI
     2ONAL VELOCITIES (DEG/SEC) /10X,2HP= F6.2,5X,2HQ= F6.2,5X,2HR= F6.2
     3//10X,30HDISPLACEMENTS (FT AND DEGREES) /10X,2HZ= F7.3,5X,4HPHI=
     4F6.2,3X,6HTHETA= F6.2//10X,27HTRAJECTORY (FT AND DEGREES) /10X,
     52HX= F8.2,4X,2HY= F8.2,4X,4HPSI= F8.2)
  501 FORMAT(1H0,9X,23HSIDESLIP ANGLE (DEG) =   F8.2,10X,21HRUDDER ANGLE
     1 (DEG) =  F8.3,10X,15HTHRUST (LBS) =   F12.1)
  505 FORMAT(///25X,28HCRAFT SPEED BELOW HUMP SPEED )
C
       END
C
       BLOCK DATA
C
       COMMON /AIR/ Z1(4)
C   IN MAIN, INCON, SIDEWL, RHS, BOWSL, STNSL, FAN
       COMMON /BMCO/ Z2(25)
C   IN MAIN, INCON, WAVES, SIDEWL, RHS, INTGRL
       COMMON /COLUMN / Z3(2)
C   IN INCON, RHS, COLFIL
       COMMON /CONST/ Z4(3)
C   IN MAIN, INCON, WAVES, SIDEWL, PROP, RUDDER, RHS, BOWSL, STNSL
       COMMON /CNTRL/ Z5(10)
C   IN INCON, RHS
       COMMON /ENGINE/ Z6(107)
C   IN MAIN, INCON, PROP, RHS
       COMMON /EQNCO/ Z7(22)
C   IN MAIN, INCON, INTGRL, COLFIL
       COMMON /FAERO/ Z8(6)
C   IN AEROD, RHS
       COMMON /FAIR/ Z9(2)
C   IN INCON, AEROD
       COMMON /FANMAP/ Z10(262)
C   IN INCON, RHS, FAN
       COMMON /FORBS/ Z11(7)
C   IN RHS, BOWSL
```

```
      COMMON /FORSS/Z12(8)                                        BLCA0260
C     IN RHS, STNSL                                               BLDA0270
      COMMON /FPRCP/ Z13(6)                                       BLDA0280
C     IN MAIN, PROP, RHS                                          BLDA0290
      COMMON /FROUDE/ Z14(2)                                      BLDA0300
C     IN MAIN, INCON, RHS                                         BLDA0310
      COMMON /FRUD/ Z15(6)                                        BLDA0320
C     IN RUDDER, RHS                                              BLDA0330
      COMMON /GBOW/ Z16(1)                                        BLDA0340
C     IN INCON, RHS                                               BLDA0350
      COMMON /GEOM/ Z17(138)                                      BLDA0360
C     IN INCON, WAVES, SIDEWL, RHS, BOWSL, STNSL                  BLDA0370
      COMMON /GEOMBS/ Z18(62)                                     BLDA0380
C     IN WAVES, RHS, BOWSL                                        BLDA0390
      COMMON /GEOMSS/ Z19(62)                                     BLCA0400
C     IN WAVES, RHS, STNSL                                        BLDA0410
      COMMON /GEOMSW/ Z20(11)                                     BLDA0420
C     IN INCON, SIDEWL                                            BLDA0430
      COMMON /KSWTCH/ Z21(1)                                      BLDA0440
C     IN SIDEWL, RHS, STNSL, INTGRL                               BLDA0450
      COMMON /LEAKER/ Z22(4)                                      BLDA0460
C     IN INCON, BOWSL, STNSL                                      BLDA0470
      COMMON /MASSES/ Z23(817)                                    BLDA0480
C     IN INCON, WAVES, SIDEWL, RUDDER, RHS, BOWSL, STNSL, INTGRL  BLDA0490
      COMMON /MATRIX/ Z24(36)                                     BLDA0500
C     IN INCON, RHS                                               BLDA0510
      COMMON /MSIDW/ Z25(55)                                      BLDA0520
C     IN SIDEWL, RHS                                              BLDA0530
      COMMON /MWAVE/ Z26(12)                                      BLDA0540
C     IN WAVES, RHS                                               BLDA0550
      COMMON /OPTION/ Z27(5)                                      ********
C     IN INCON, RHS                                               BLDA0570
      COMMON /PLENUM/ Z28(4)                                      BLDA0580
C     IN INCON, WAVES, SIDEWL, RHS                                BLDA0590
      COMMON /PRIME/ Z29(5)                                       BLDA0600
C     IN MAIN, INCON, SIDEWL, RHS, INTGRL                         BLDA0610
      COMMON /PRTINT/ Z30(12)                                     BLDA0620
C     IN MAIN, INCON, WAVES, SIDEWL, PROP, RUDDER, AEROD, RHS, BOWSL,   BLDA0630
C        STNSL, FAN, INTGRL                                       BLCA0640
      COMMON /PWAVE/ Z31(2)                                       BLDA0650
C     IN INCON, RHS                                               BLDA0660
      COMMON /RISER/ Z32(1)                                       BLDA0670
C     IN INCON, WAVES                                             BLDA0680
      COMMON /ROLL/ Z33(2)                                        BLDA0690
C     IN MAIN, INCON                                              BLDA0700
      COMMON /RUDDR/ Z34(62)                                      BLDA0710
C     IN MAIN, INCON, PROP, RUDDER, RHS                           BLDA0720
      COMMON /SIDE/ Z35(22)                                       BLDA0730
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C     IN INCON, WAVES, SIDEWL, RHS                                       BLDA0740
        COMMON /SOFTBS/ Z36(20)                                          BLDA0750
C     IN INCON, RHS, BOWSL, FAN                                          BLDA0760
        COMMON /SOFTSS/ Z37(19)                                          BLDA0770
C     IN INCON, RHS, STNSL, FAN                                          BLDA0780
        COMMON /STABLE/ Z38(5)                                           BLDA0790
C     IN INCON, INTGRL                                                   BLDA0800
        COMMON /STSLR/ Z39(2)                                            BLDA0810
C     IN INCON, STNSL                                                    BLDA0820
        COMMON /VALOLD/ Z40(20)                                          BLDA0830
C     IN MAIN, INCON, RHS, STNSL, INTGRAL                                BLDA0840
        COMMON /VARBLE/ Z41(40)                                          BLDA0850
C     IN MAIN, INCON, WAVES, SIDEWL, PROP, RUDDER, AEROD, RHS, BOWSL,    BLDA0860
C        STNSL, FAN, INTGRL                                              BLDA0870
        COMMON /WAVE/ Z42(80)                                            BLDA0880
C     IN MAIN, INCON, WAVES, SIDEWL, RHS, BOWSL, STNSL                   BLDA0890
        COMMON /WAVEF / Z43(40)                                          BLDA0900
C     IN INCON                                                           BLDA0910
        COMMON /SLOPE/Z44(5)                                             BLDA0920
C     IN INCON, RHS, BOWSL                                               BLDA0930
        COMMON /PROMOD/ Z45(7)                                           BLDA0940
C     IN MAIN AND ALL SUBROUTINES                                        BLDA0950
C                                                                        BLDA0960
        DATA Z1/4*0.0/                                                   BLDA0970
        DATA Z2/25*0.0/                                                  BLDA0980
        DATA Z3/2*0.0/                                                   BLDA0990
        DATA Z4/3*0.0/                                                   BLDA1000
        DATA Z5/10*0.0/                                                  BLDA1010
        DATA Z6/107*0.0/                                                 BLDA1020
        DATA Z7/21*0.0/                                                  BLDA1030
        DATA Z8/6*0.0/                                                   BLDA1040
        DATA Z9/2*0.0/                                                   BLDA1050
        DATA Z10/262*0.0/                                                BLDA1060
        DATA Z11/7*0.0/                                                  BLDA1070
        DATA Z12/8*0.0/                                                  BLDA1080
        DATA Z13/6*0.0/                                                  BLDA1090
        DATA Z14/2*0.0/                                                  BLDA1100
        DATA Z15/6*0.0/                                                  BLDA1110
        DATA Z16/0.0/                                                    BLDA1120
        DATA Z17/138*0.0/                                                BLDA1130
        DATA Z18/62*0.0/                                                 BLDA1140
        DATA Z19/62*0.0/                                                 BLDA1150
        DATA Z20/11*0.0/                                                 BLDA1160
        DATA Z21/0.0/                                                    BLDA1170
        DATA Z22/4*0.0/                                                  BLDA1180
        DATA Z23/817*0.0/                                                BLDA1190
        DATA Z24/36*0.0/                                                 BLDA1200
        DATA Z25/55*0.0/                                                 BLDA1210
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      DATA Z26/12*0.0/                                                  BLDA1220
      DATA Z27/5*0.0/                                                   ********
      DATA Z28/4*0.0/                                                   BLDA1240
      DATA Z29/5*0.0/                                                   BLDA1250
      DATA Z30/12*0.0/                                                  BLDA1260
      DATA Z31/2*0.0/                                                   BLDA1270
      DATA Z32/0.0/                                                     BLDA1280
      DATA Z33/2*0.0/                                                   BLDA1290
      DATA Z34/62*0.0/                                                  BLDA1300
      DATA Z35/22*0.0/                                                  BLDA1310
      DATA Z36/20*0.0/                                                  BLDA1320
      DATA Z37/19*0.0/                                                  BLDA1330
      DATA Z38/5*0.0/                                                   BLDA1340
      DATA Z39/2*0.0/                                                   BLDA1350
      DATA Z40/20*0.0/                                                  BLDA1360
      DATA Z41/40*0.0/                                                  BLDA1370
      DATA Z42/80*0.0/                                                  BLDA1380
      DATA Z43/40*0.0/                                                  BLDA1390
      DATA Z44/5*0.0/                                                   BLDA1400
      DATA Z45/7*0.0/                                                   BLDA1410
C                                                                       BLDA1420
      END                                                               BLDA1430
C                                                                       AER 0010
      SUBROUTINE AEROD                                                  AER 0020
C                                                                       AER 0030
                                                                        AER 0040
      INTEGER ON                                                        AER 0050
      COMMON /FAERO/ FX,FY,FZ,FK,FM,FN                                  AER 0060
      COMMON /FAIR/ RHOA,XLAERO                                         AER 0070
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7  AER 0080
      COMMON /PRTINT/ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,  AER 0090
     -IRUC,IPROP,IAEROD,IRHS                                            AER 0100
      COMMON /VARBLE/ VAL(40)                                           AER 0110
      EQUIVALENCE            (VAL(2),U),(VAL(3),V),(VAL(4),W),          AER 0120
     1(VAL(5),P),(VAL(6),Q),(VAL(7),R),(VAL(8),PHI),(VAL(9),THETA),     AER 0130
     2(VAL(10),Z),(VAL(11),BMASS),(VAL(21),X),(VAL(22),Y),(VAL(23),PSI),AER 0140
     3(VAL(24),PB)                                                      AER 0150
C                                                                       AER 0160
      QA=RHOA*U*U                                                       AER 0170
      QAL=QA*XLAERO                                                     AER 0180
      BETA=-V/U                                                         AER 0190
      BETASQ=BETA*BETA                                                  AER 0200
      FX=-(0.90*BETASQ+0.13)*QA                                         AER 0210
      FY=(0.0*BETASQ+0.53*BETA)*QA                                      AER 0220
      FZ=-(2.06*BETASQ+0.39)*QA                                         AER 0230
      FK=-(0.5*BETASQ+0.0*BETA)*QAL                                     AER 0240
      FM=(0.29*BETASQ+0.12)*QAL                                         AER 0250
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      FN=(0.0*BETASQ+0.076*BETA)*QAL                                    AER 0260
      IF (IAEROD.NE.ON) RETURN                                          AER 0270
                WRITE(6,100) FX,FY,FZ,FK,FM,FN                          AER 0280
C                                                                       AER 0290
  100 FORMAT(/10X,23HAEROD FX,FY,FZ,FK,FM,FN/6E15.4)                    AER 0300
C                                                                       AER 0310
      RETURN                                                            AER 0320
      END                                                               AER 0330
C                                                                       BWSL0010
      SUBROUTINE BOWSL                                                  BWSL0020
C                                                                       BWSL0030
      INTEGER ON                                                        BWSL0040
      COMMON /AIR/ PINF,RHOINF,GAM,IQUIT                                BWSL0050
      COMMON /CONST/ PI,RAD,UO                                          BWSL0060
      COMMON /FORBS/ FX,FY,FZ,FK,FM,FN,CL                               BWSL0070
      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,BWSL0080
     110),XCF,ZCP                                                       BWSL0090
      COMMON /GEOMBS/ DETABX(11),DETABT(11),ARM1B(10),ARM2B(10),DFBS(10)BWSL0100
     1,TSKIB(10)                                                        BWSL0110
      COMMON /LEAKER/ ALEAK,BLEAK,CFSS,CFBS                             BWSL0120
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AMBWSL0130
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO                         BWSL0140
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IBWSL0150
     1RUD,IPROP,IAEROD,IRHS                                             BWSL0160
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7  BWSL0170
      COMMON /SLOPE/ WATSLP,XPWV,XLXPWV,PWVHT,XPWVXS                    BWSL0180
      COMMON /SOFTBS/ XBF,PBS,SINBS,COSBS,XBS,ZBS,DELYBS,DPBS,ELMAXB,YAVBWSL0190
     1GE(10),CENCAB                                                     BWSL0200
      COMMON /VARBLE/ VAL(40)                                           BWSL0210
      COMMON /WAVE/ ETA(4,11),AW(10),OMEGA(10),DVCLW,NWAVE,BETA,FXWAV,FYBWSL0220
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBBWSL0230
     2BAR                                                               BWSL0240
      DIMENSION ELSKID(11), WETLEN(11), BWSL(6,24), GAP(11), ELSKI(11), BWSL0250
     1DPFT(11), WTAB(6), ZTAB(6)                                        BWSL0260
      DATA NPTS,IBS/6,0/                                                BWSL0270
      DATA WTAB/0.0,3.75,5.42,6.67,7.5,8.42/                            BWSL0280
      DATA ZTAB/3.75,4.00,4.42,4.83,5.25,5.67/                          BWSL0290
      DATA ENU,UWSKI,CLSKI,HINGHT/1.28E-05,0.0,1.5708,1.875/            BWSL0300
      DATA BWSL/0.0,3.8,6.9,9.9,12.3,15.0,0.0,4.1,7.3,10.5,13.2,15.7,0.0BWSL0310
     1,4.3,7.7,11.0,13.7,16.7,0.0,4.7,8.2,11.5,14.5,17.4,0.0,5.2,8.9,12.BWSL0320
     24,15.4,18.3,0.0,5.5,9.6,13.3,16.1,19.6,0.0,5.8,9.9,13.8,17.1,20.6,BWSL0330
     30.0,6.1,10.6,14.7,18.4,21.9,0.0,6.4,11.0,15.3,19.3,23.3,0.0,6.6,11BWSL0340
     4.7,16.4,20.5,24.5,0.0,6.9,12.3,17.6,22.1,25.7,0.0,7.2,13.5,19.6,24BWSL0350
     5.1,28.3,0.0,8.2,15.3,21.7,26.3,31.3,0.0,9.6,17.5,24.2,29.7,34.6,0.BWSL0360
     60,11.9,20.0,26.7,32.3,38.0,0.0,14.0,22.5,30.0,35.8,41.0,0.0,17.5,2BWSL0370
     75.5,32.5,39.7,44.5,0.0,21.0,30.0,37.4,42.0,47.0,0.0,24.6,33.7,41.0BWSL0380
     8,45.0,48.7,0.0,29.4,38.5,45.0,48.7,48.7,0.0,33.0,45.0,48.7,48.7,48BWSL0390
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9.7,0.0,40.0,48.7,48.7,48.7,48.7,0.0,48.7,48.7,48.7,48.7,48.7,0.0,48WSL0400
$8.7,48.7,48.7,48.7,48.7/                                               BWSL0410
 DATA CORLEN/3.75/                                                      BWSL0420
 EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VABWSL0430
1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VABWSL0440
2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)BWSL0450
3, (VAL(24),PB)                                                         BWSL0460
C                                                                       BWSL0470
 DO 1 J=1,11                                                            BWSL0480
 GAP(J) = 0.0                                                           BWSL0490
 ELSKI(J) = 0.0                                                         BWSL0500
 WETLEN(J) = 0.0                                                        BWSL0510
 ELSKID(J) = 0.0                                                        BWSL0520
1 CONTINUE                                                              BWSL0530
 ALBS = 0.0                                                             BWSL0540
 FX = 0.0                                                               BWSL0550
 FZ = 0.0                                                               BWSL0560
 FK = 0.0                                                               BWSL0570
 FM = 0.0                                                               BWSL0580
 FN = 0.0                                                               BWSL0590
 DELPBG = PBS-PB                                                        BWSL0600
 IF (DELPBG.LT.0.0) DELPBG=0.0                                          BWSL0610
 PBAR = PB-PINF                                                         BWSL0620
 DELP = PBAR                                                            BWSL0630
 IF (DELP.LT.0.0) DELP=0.0                                              BWSL0640
 ARGO = ELMAXB/CORLEN                                                   BWSL0650
 ANGO = ARSIN(ARGO)                                                     BWSL0660
 X1 = XBS+ZBS*THETA-CORLEN*COS(ANGO)                                    BWSL0670
 Z1 = -Z-ZBS+XBS*THETA-ELMAXB*COS(THETA)                                BWSL0680
 DPTHFT = (5.5/(1.+(U/25.))**2.0)/12.0                                  BWSL0690
 IF (CENCAB.GT.1.1875) CENCAB=1.1875                                    BWSL0700
 N = NSTA(3)                                                            BWSL0710
 DO 3 K=1,N                                                             BWSL0720
 DPFT(K) = DPTHFT                                                       BWSL0730
 ELSKI(K) = (ETA(3,K)-DETABX(K)*(XX(3,K)-X1)-Z1)+YY(3,K)*PHI+XLXPWVBWSL0740
1*WATSLP                                                                BWSL0750
 IF (ELSKI(K).GT.HINGHT) ELSKI(K)=HINGHT                                BWSL0760
 IF ((HINGHT-ELSKI(K)+DPFT(K)).GE.ELMAXB) DPFT(K)=ELMAXB-HINGHT+ELSBWSL0770
1KI(K)                                                                  BWSL0780
 IF (DPFT(K).LT.0.0) DPFT(K)=0.0                                        BWSL0790
 ELSKID(K) = (ELSKI(K)-DPFT(K))*12.0                                    BWSL0800
 IF ((HINGHT-ELSKID(K)/12.0).GE.ELMAXB) ELSKID(K)=(HINGHT-ELMAXB)*1BWSL0810
12.0                                                                    BWSL0820
 DPIN = DPFT(K)*12.0                                                    BWSL0830
 MM = DPIN                                                              BWSL0840
 MM1 = MM+1                                                             BWSL0850
 MM2 = MM1+1                                                            BWSL0860
 DINC = DPIN-MM                                                         BWSL0870
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      GAP(K) = -ELSKI(K)+(HINGHT-ELMAXB)                                BWSL0880
      IF (GAP(K).LT.0.0) GAP(K)=0.0                                     BWSL0890
      IF (ELSKID(K).GE.0.) GO TO 2                                      BWSL0900
      WETLEN(K) = ELSKI(K)                                              BWSL0910
      GO TO 3                                                           BWSL0920
    2 MM3 = ELSKID(K)                                                   BWSL0930
      MM4 = MM3+1                                                       BWSL0940
      MM5 = MM4+1                                                       BWSL0950
      DLINC = ELSKID(K)-MM3                                             BWSL0960
      BWSL1 = BWSL(MM1,MM4)                                             BWSL0970
      BWSL2 = BWSL(MM1,MM5)                                             BWSL0980
      BWSL3 = BWSL(MM2,MM4)                                             BWSL0990
      BWSL4 = BWSL(MM2,MM5)                                             BWSL1000
      BWSLA1 = (BWSL2-BWSL1)*DLINC+BWSL1                                BWSL1010
      BWSLA2 = (BWSL4-BWSL3)*DLINC+BWSL3                                BWSL1020
      WETLEN(K) = ((BWSLA2-BWSLA1)*DINC+BWSLA1)/12.0                    BWSL1030
    3 CONTINUE                                                          BWSL1040
      N = NSTA(3)-1                                                     BWSL1050
      DO 10 J=1,N                                                       BWSL1060
      WETLAV = (WETLEN(J+1)+WETLEN(J))/2.0                              BWSL1070
      IF (WETLAV.LE.0.001) GO TO 8                                      BWSL1080
      DPFTAV = (DPFT(J+1)+DPFT(J))/2.0                                  BWSL1090
      ELSKIA = (ELSKI(J+1)+ELSKI(J))/2.0                                BWSL1100
      ELSKDA = (ELSKID(J+1)+ELSKID(J))/24.0                             BWSL1110
      SEALHT = HINGHT-ELSKDA                                            BWSL1120
      DIFF = 2.0*CENCAB-(SEALHT+0.5)                                    BWSL1130
      IF (DIFF.GT.0.5) DIFF=0.5                                         BWSL1140
      ARM1B(J) = X1+WETLAV/2.0                                          BWSL1150
      ARM2B(J) = ZS-ELSKIA+DPFTAV/2.0                                   BWSL1160
      IF (DIFF.GE.0.25) GO TO 4                                         BWSL1170
      DFBS(J) = -DELP*DELYBS*WETLAV                                     BWSL1180
      GO TO 7                                                           BWSL1190
    4 FORLEN = XBF-WETLAV                                               BWSL1200
      IF (FORLEN.EQ.0.0) GO TO 5                                        BWSL1210
      ARGW = (HINGHT-ELSKIA)/FORLEN                                     BWSL1220
      IF (ARGW.GT.1.0) ARGW=1.0                                         BWSL1230
      ANGW = ARSIN(ARGW)                                                BWSL1240
      FORCOS = COS(ANGW)                                                BWSL1250
      GO TO 6                                                           BWSL1260
    5 FORCOS = 0.0                                                      BWSL1270
    6 DFBS(J) = -DELP*DELYBS*WETLAV-DELP*FORLEN*DELYBS*FORCOS*((FORLEN*0BWSL1280
     1.5*FORCOS)/(FORLEN*FORCOS+WETLAV/2.0))*((DIFF-0.25)*4.0)          BWSL1290
    7 ARG = 0.5*RHO*U*U*WETLAV*DELYBS                                   BWSL1300
      RESKI = U*WETLAV/ENU                                              BWSL1310
      CDTSKI = 0.427/(ALOG10(RESKI)-0.407)**2.64                        BWSL1320
      TSKIB(J) = -ARG*CDTSKI                                            BWSL1330
      GO TO 9                                                           BWSL1340
    8 DFBS(J) = 0.0                                                     BWSL1350
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      TSKIB(J) = 0.0                                                    BWSL1360
    5 CONTINUE                                                          BWSL1370
      FX = FX+TSKIB(J)                                                  BWSL1380
      FZ = FZ+DFBS(J)                                                   BWSL1390
      FK = FK+DFBS(J)*YAVGB(J)                                          BWSL1400
      FM = FM-DFBS(J)*ARM1B(J)+TSKIB(J)*ARM2B(J)                        BWSL1410
      FN = FN-TSKIB(J)*YAVGB(J)                                         BWSL1420
      ALBS = ALBS+(GAP(J)+GAP(J+1))*DELYBS/2.0                          BWSL1430
   10 CONTINUE                                                          BWSL1440
      ALBS = ALBS+BLEAK                                                 BWSL1450
      SQFAC = SQRT(2.*ABS(PBAR)/RHOINF)                                 BWSL1460
      CL = CFBS*ALBS*SQFAC*SIGN(1.,PBAR)                                BWSL1470
      IF (IBOWSL.NE.ON) RETURN                                          BWSL1480
      WRITE (6,11) GAP,WETLEN,FX,FY,FZ,FK,FM,FN                         BWSL1490
C                                                                       BWSL1500
   11 FORMAT (//10X,8HBOW SEAL/26H GAP (FT.) (PORT TO STBD.)/11F10.5/28HBWSL1510
     1 WETLEN(FT.) (PORT TO STBD.)/11F10.5/10X,23HBOWSL  FX,FY,FZ,FK,FM,FBWSL1520
     2N/6E15.4)                                                         BWSL1530
C                                                                       BWSL1540
      RETURN                                                            BWSL1550
      END                                                               BWSL1560
C                                                                       CFL 0010
      SUBROUTINE COLFIL                                                 CFL 0020
C                                                                       CFL 0030
      COMMON/AXIS/NXYS(26)                                              CFL 0040
      COMMON/COLUMN/IVERT,ILATRL                                        CFL 0050
      COMMON /CURVE/NCURV(10)                                           CFL 0060
      COMMON/EQNCO/ NEQS,TOL(20),JQQ                                    CFL 0070
      COMMON/GRAF/NGRAF,NDRW                                            CFL 0080
      COMMON /HEADG/TICRD(6)                                            CFL 0090
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7  CFL 0100
      COMMON/STEP/ STEP2                                                CFL 0110
      COMMON /SUM/ ISUM1(8),ISUM2(8)                                    CFL 0120
      REAL*8 TICRD                                                      CFL 0130
      REAL LABEL                                                        CFL 0140
      REAL LAB(4)/'    ','   1','   2','   3'/                          CFL 0150
      REAL*8 NAMES(52)/'TIME    ','        ','AIR MASS',' (BMASS)','Z DICFL 0160
     1SPLA','CEMENT  ','PITCH AN','GLE     ','PLENUM P','RESSURE ','BOW CFL 0170
     2ACCE','LERATION','C.G.ACCE','LERATION','FAN POWE','R(IDEAL)','BOWCFL 0180
     3 SEAL','PRESSURE','STN SEAL','PRESSURE','   WAVE ','HEIGHT  ','SPECFL 0190
     4ED TH','RU WATER','ROLL RAT','E       ','PLENUM V','OLUME   ','X DCFL 0200
     5ISPLA','CEMENT  ','Y DISPLA','CEMENT  ','AIR FLOW',' IN     ','AIRCFL 0210
     6 FLOW',' OUT    ','NET FORC','E X DIR ','WAVE FOR','CE X DIR','THRCFL 0220
     7UST S','TARBOARD','THRUST P','ORT SIDE','  PITCH ','RATE    ','STECFL 0230
     8RN SE','AL LIFT ','STERN SE','AL DRAG ','  ROLL A','NGLE    '/   CFL 0240
      REAL*8 TITLE(12)                                                  CFL 0250
      REAL*8 LINE2(2)/'PLOT IS ',' VERSUS '/                            CFL 0260
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      REAL*8 NAMEX(2),NAMEY(2),INAME(16)
      EQUIVALENCE (TITLE(1),TICRD(1)),(TITLE(2),TICRD(2)),(TITLE(3),TI
     1CRD(3)),(TITLE(4),TICRD(4)),(TITLE(5),TICRD(5)),(TITLE(6),TICRD(
     26))
      DIMENSION PVQQ(26),XOUT(900),YOUT(900),AFILE(8)
      DIMENSION THSTS(1), THSTP(1)
      EQUIVALENCE (PVQQ(1),TIME),(PVQQ(2),BMASS),(PVQQ(3),Z),(PVQQ(4),TH
     1ETA),(PVQQ(5),PBAR),(PVQQ(6),BOWACC),(PVQQ(7),ACC),(PVQQ(8),FANPWR
     2),(PVQQ(9),PBARB),(PVQQ(10),PBARS),(PVQQ(11),ETA),(PVQQ(12),U),(PV
     3QQ(13),PDEG),(PVQQ(14),VOLP),(PVQQ(15),X),(PVQQ(16),Y),(PVQQ(17),Q
     4IN),(PVQQ(18),QOUT),(PVQQ(19),GFXXX),(PVQQ(20),FXPWAV),(PVQQ(21),T
     5HSTS(1)),(PVQQ(22),THSTP(1)),(PVQQ(23),QDEG),(PVQQ(24),FZSS),(PVQQ
     6(25),FXSS),(PVQQ(26),PHI)
C
      IF(JQQ.NE.2) GO TO 1
      WRITE(6,777) STEP2
  777 FORMAT('0',4X,'THIS RUN USED VARIABLE STEP SIZE',/,'0',4X,'THE MIN
     1IMUM STEPSIZE RECORDED DURING THE RUN WAS',2X,E30.5)
    1 ENDFILE 1
      REWIND 1
      TITLE(7)=LINE2(1)
      TITLE(10)=LINE2(2)
      IF(NGRAF.EQ.0) GO TO 11
      J=1
      NGF=NGRAF
      INDEX=NGRAF*2
      DO 19 I=1,INDEX,2
      INDX=NXYS(I)
      INDY=NXYS(I+1)
      IQ=0
    7 READ(1,END=8)TIME,BMASS,Z,THETA,PBAR,BOWACC,ACC,FANPWR,PBARB,PBARS
     1,ETA,U,PDEG,VOLP,X,Y,QIN,QOUT,GFXXX,FXPWAV,THSTS(1),THSTP(1),QDEG,
     2FZSS,FXSS,PHI
      IF(IQ.GE.900) GO TO 8
      IQ=IQ+1
      XOUT(IQ)=PVQQ(INDX)
      YOUT(IQ)=PVQQ(INDY)
      GO TO 7
    8 REWIND 1
      INX=INDX*2
      INY=INDY*2
      NAMEX(1)=NAMES(INX-1)
      NAMEX(2)=NAMES(INX)
      NAMEY(1)=NAMES(INY-1)
      NAMEY(2)=NAMES(INY)
      IF(NDRW.EQ.1) GO TO 20
C
      CALL PLOTP(XOUT,YOUT,-IQ,0)
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C
      WRITE(6,301) NAMEX,NAMEY
  301 FORMAT(' ',20X,2A8,' IS THE INDEPENDENT VARIABLE AND ',2A8,' THE D
     1EPENDENT VARIABLE')
      GO TO 19
   20 TITLE(8)=NAMEY(1)
      TITLE(9)=NAMEY(2)
      TITLE(11)=NAMEX(1)
      TITLE(12)=NAMEX(2)
      NCUR=NCURV(J)
      IF(NCUR.NE.0) GO TO 25
      LABEL=LAB(1)
C
      CALL DRAW(IQ,XOUT,YOUT,NCUR,0,LABEL,TITLE,0,0,0,0,0,0,8,8,0,LAST)
C
      J=J+1
      GO TO 19
   25 WRITE(2)IQ,NCUR,NGF,LABEL,(TITLE(K),K=1,12),(XOUT(L),YOUT(L),L=1,I
     1Q)
      NGF=NGF-1
   19 CONTINUE
      IF((NGF.EQ.0).AND.(NCUR.EQ.3)) GO TO 26
   11 IF(IVERT.NE.1) GO TO 14
      WRITE(6,100)
  100 FORMAT('0',50X,'***SUMMARY ONE***',/,'0')
      K=0
      DO 31 I=1,8
      IF(ISUM1(I).NE.0) K=K+1
   31 CONTINUE
      NUM1=K
      IF(K.EQ.0) GO TO 14
      N=K*2
      J=1
      DO 33 I=1,NUM1
      IDEX=ISUM1(I)*2
      INAME(J)=NAMES(IDEX-1)
      INAME(J+1)=NAMES(IDEX)
      J=J+2
   33 CONTINUE
       WRITE(6,300)(INAME(I),I=1,N)
  300 FORMAT('0',16A8)
      GO TO 4
   26 ENDFILE 2
      REWIND 2
      NGF=NGRAF
      J=1
   27 READ(2,END=38)IQ,NCUR,NGRAF,LABEL,(TITLE(K),K=1,12),(XOUT(L),YOUT(
     1L),L=1,IQ)
```

```
      IF((NGF.EQ.NGRAF).AND.(NCUR.EQ.J)) GO TO 29                       CFL 1230
      GC TO 27                                                          CFL 1240
   29 LABEL=LAB(J+1)                                                    CFL 1250
C                                                                       CFL 1260
      CALL DRAW(IC,XOUT,YOUT,NCUR,0,LABEL,TITLE,0,0,0,0,0,0,8,8,0,LAST) CFL 1270
C                                                                       CFL 1280
      REWIND 2                                                          CFL 1290
      J=J+1                                                             CFL 1300
      IF(J.EQ.4) GO TO 38                                               CFL 1310
      GC TO 27                                                          CFL 1320
   38 NGF=NGF-1                                                         CFL 1330
      IF(NGF.EQ.0) GO TO 11                                             CFL 1340
      J=1                                                               CFL 1350
      GC TO 27                                                          CFL 1360
    4 READ(1,END=13)(PVQQ(I),I=1,26)                                    CFL 1370
      DC 35 I=1,NUM1                                                    CFL 1380
      J=ISUM1(I)                                                        CFL 1390
   35 AFILE(I)=PVCQ(J)                                                  CFL 1400
      WRITE(6,400)(AFILE(I),I=1,NUM1)                                   CFL 1410
400   FCRMAT('0',8(3X,F10.4,3X))                                        ********
      GC TO 4                                                           CFL 1430
   13 REWIND 1                                                          CFL 1440
   14 IF(ILATRL.NE.1) GO TO 17                                          CFL 1450
      WRITE(6,200)                                                      CFL 1460
  200 FCRMAT('0',50X,'***SUMMARY TWO***',/,'0')                         CFL 1470
      K=C                                                               CFL 1480
      DC 32 I=1,8                                                       CFL 1490
      IF(ISUM2(I).NE.0) K=K+1                                           CFL 1500
   32 CCNTINUE                                                          CFL 1510
      NUM2=K                                                            CFL 1520
      IF(K.EQ.0) GO TO 16                                               CFL 1530
      N=K*2                                                             CFL 1540
      J=1                                                               CFL 1550
      DC 34 I=1,NUM2                                                    CFL 1560
      IDEX=ISUM2(I)*2                                                   CFL 1570
      INAME(J)=NAMES(IDEX-1)                                            CFL 1580
      INAME(J+1)=NAMES(IDEX)                                            CFL 1590
      J=J+2                                                             CFL 1600
   34 CCNTINUE                                                          CFL 1610
       WRITE(6,30C)(INAME(I),I=1,N)                                     CFL 1620
   23 READ(1,END=16)(PVQQ(I),I=1,26)                                    CFL 1630
      DC 36 I=1,NUM2                                                    CFL 1640
      J=ISUM2(I)                                                        CFL 1650
   36 AFILE(I)=PVCQ(J)                                                  CFL 1660
      WRITE(6,400)(AFILE(I),I=1,NUM2)                                   CFL 1670
      GC TO 23                                                          CFL 1680
   16 REWIND 1                                                          CFL 1690
   17 RETURN                                                            CFL 1700
```

```
      END                                                               CFL 1710
C                                                                       DMV 0010
      SLBROUTINE DMINV (A,N,D)                                          DMV 0020
C                                                                       DMV 0030
      CIMENSION A(6,6),PIVOT(6)                                         DMV 0040
      DIMENSICN IPVOT(6),INDEX(6,2)                                     DMV 0050
      ECLIVALENCE (IROW,JRCW),(ICOL,JCCL)                               DMV 0060
C                                                                       DMV 0070
      C=1.0                                                             DMV 0080
      CC 17 J=1,N                                                       DMV 0090
      IPVCT(J)=0                                                        DMV 0100
   17 CCNTINUE                                                          DMV 0110
      DC 135 I=1,N                                                      DMV 0120
      T=0.0                                                             DMV 0130
        CC 9 J=1,N                                                      DMV 0140
      IF(IPVOT(J)-1) 13,9,13                                            DMV 0150
   13 DC 23 K=1,N                                                       DMV 0160
      IF(IPVOT(K)-1) 43,23,81                                           DMV 0170
   43 IF (ABS(T)-ABS(A(J,K))) 83,23,23                                  DMV 0180
   83 IRCW=J                                                            DMV 0190
      ICCL=K                                                            DMV 0200
      T=A(J,K)                                                          DMV 0210
   23 CCNTINUE                                                          DMV 0220
    9 CCNTINUE                                                          DMV 0230
      IPVCT(ICOL)=IPVOT(ICOL)+1                                         DMV 0240
      IF(IROW-ICOL) 73,109,73                                           DMV 0250
   73 C=-D                                                              DMV 0260
      CC 12 L=1,N                                                       DMV 0270
      T=A(IROW,L)                                                       DMV 0280
      A(IROW,L)=A(ICOL,L)                                               DMV 0290
      A(ICOL,L)=T                                                       DMV 0300
   12 CCNTINUE                                                          DMV 0310
  109 INCEX(I,1)=IROW                                                   DMV 0320
      INCEX(I,2)=ICOL                                                   DMV 0330
      PIVOT(I)=A(ICOL,ICOL)                                             DMV 0340
      C=C*PIVCT(I)                                                      DMV 0350
      A(ICCL,ICOL)=1.0                                                  DMV 0360
      CC 205 L=1,N                                                      DMV 0370
      A(ICCL,L)=A(ICOL,L)/PIVOT(I)                                      DMV 0380
  205 CCNTINUE                                                          DMV 0390
      DC 134 LI=1,N                                                     DMV 0400
      IF(LI-ICOL) 21,134,21                                             DMV 0410
   21 T=A(LI,ICOL)                                                      DMV 0420
      A(LI,ICOL)=0.0                                                    DMV 0430
      DC 89 L=1,N                                                       DMV 0440
      A(LI,L)=A(LI,L)-A(ICOL,L)*T                                       DMV 0450
   89 CCNTINUE                                                          DMV 0460
```

```
  134 CONTINUE                                                              DMV 0470
  135 CONTINUE                                                              DMV 0480
      DO 3 I=1,N                                                            DMV 0490
      L=N-I+1                                                               DMV 0500
      IF(INDEX(L,1)-INDEX(L,2)) 19,3,19                                     DMV 0510
   19 JROW=INDEX(L,1)                                                       DMV 0520
      JCOL=INDEX(L,2)                                                       DMV 0530
      DO 549 K=1,N                                                          DMV 0540
      T=A(K,JROW)                                                           DMV 0550
      A(K,JROW)=A(K,JCOL)                                                   DMV 0560
      A(K,JCOL)=T                                                           DMV 0570
  549 CONTINUE                                                              DMV 0580
    3 CONTINUE                                                              DMV 0590
C                                                                           DMV 0600
   81 RETURN                                                                DMV 0610
      END                                                                   DMV 0620
C                                                                           FAN 0010
      SUBROUTINE FAN                                                        FAN 0020
C                                                                           FAN 0030
      INTEGER ON                                                            FAN 0040
      COMMON /AIR/ PINF,RHOINF,GAM,IQUIT                                    FAN 0050
      COMMON /FANMAP/ CIN,QBFAN(25),QMFAN(25),QSFAN(25),ENBFAN,ENMFAN,ENFAN 0060
     1SFAN,BRPM,EMRPM,SRPM,NPTSB,NPTSM,NPTSS,PBFAN(25),PMFAN(25),PSFAN(2FAN 0070
     25),TMEB(25),DELB(25),NB,TMES(25),DELS(25),NS                         FAN 0080
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7   FAN 0090
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IFAN 0100
     1RUD,IPROP,IAEROD,IRHS                                                 FAN 0110
      COMMON /SOFTBS/ XBF,PBS,SINBS,COSBS,XBS,ZBS,DELYBS,DPBS,ELMAXB,YAVFAN 0120
     1GE(10)                                                                FAN 0130
      COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,DELYSS,DPSS,ELMAXS,YAVFAN 0140
     1GS(10)                                                                FAN 0150
      COMMON /VARBLE/ VAL(40)                                               FAN 0160
      DIMENSION QB(1), QM(1), QS(1), PBOW(1), PM(1), PS(1), HP(8)           FAN 0170
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VAFAN 0180
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VAFAN 0190
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)FAN 0200
     3, (VAL(24),PB)                                                        FAN 0210
      EQUIVALENCE (VAL(18),FANPWR)                                          FAN 0220
      EQUIVALENCE (VAL(35),PBARB),(VAL(36),PBARS)                           ********
      EQUIVALENCE (QBFAN(1),QB(1)), (QMFAN(1),QM(1)), (QSFAN(1),QS(1)),  FAN 0230
     1(PBFAN(1),PBOW(1)), (PMFAN(1),PM(1)), (PSFAN(1),PS(1))                FAN 0240
      DATA HP/2.9,2.3,1.95,1.77,1.85,2.05,1.93,1.62/                        FAN 0250
C                                                                           FAN 0260
      ERAT = 8000/BRPM                                                      FAN 0270
      EMRAT = 8000/EMRPM                                                    FAN 0280
      SRAT = 8000/SRPM                                                      FAN 0290
      TL = VAL(1)                                                           FAN 0300
```

```
      IF (NB.EQ.0.0) GO TO 1
      DPBS = FG1(TL,NB,TMEB,DELB,ILB)
      PBS = PB+DPBS
    1 IF (NS.EQ.0.0) GO TO 2
      DPSS = FG1(TL,NS,TMES,DELS,ILS)
      PSS = PB+DPSS
    2 CONTINUE
      PB1 = PBS-PINF
      PB2 = PB-PINF
      PB3 = PSS-PINF
      PBARB = PB1*BRAT**2
      PBARM = PB2*EMRAT**2
      PBARS = PB3*SRAT**2
      QBOW = ENBFAN*FG1(PBARB,NPTSB,PBOW,QB,IB)/BRAT
      QMAIN = ENMFAN*FG1(PBARM,NPTSM,PM,QM,IM)/EMRAT
      QSTN = ENSFAN*FG1(PBARS,NPTSS,PS,QS,IS)/SRAT
      QIN = QBOW+QMAIN+QSTN
      MB1 = (QBOW/ENBFAN+5.0)/5.0
      MB2 = MB1+1
      MB3 = MB2+1
      BINC = ((QBOW/ENBFAN+5.0)-MB1*5.0)/5.0
      BFANHP = ((HP(MB3)-HP(MB2))*BINC+HP(MB2))*ENBFAN*(1./BRAT)**3.0
      MS1 = (QSTN/ENSFAN+5.0)/5.0
      MS2 = MS1+1
      MS3 = MS2+1
      STINC = ((QSTN/ENSFAN+5.0)-MS1*5.0)/5.0
      SFANHP = ((HP(MS3)-HP(MS2))*STINC+HP(MS2))*ENSFAN*(1./SRAT)**3.0
      MM1 = (QMAIN/ENMFAN+5.0)/5.0
      MM2 = MM1+1
      MM3 = MM2+1
      PLINC = ((QMAIN/ENMFAN+5.0)-MM1*5.0)/5.0
      PFANHP = ((HP(MM3)-HP(MM2))*PLINC+HP(MM2))*ENMFAN*(1./EMRAT)**3.0
      RELPWR = PFANHP+BFANHP+SFANHP
      FANPWR = (QBOW*PB1+QMAIN*PB2+QSTN*PB3)/550.
      FANEFF = FANPWR/RELPWR
      IF (IRHS.NE.CN) RETURN
      WRITE (6,3) QBOW,QMAIN,QSTN,PBARB,PBARM,PBARS,RELPWR,FANPWR,FANEFF
C
    3 FORMAT (//4H FAN/32H Q - BOW,MAIN,STERN (CU FT /SEC)3F12.1/28H DEL
     1P - BOW,MAIN,STERN (PSF)3F11.2/60H ACTUAL FAN POWER REQUIRED(HP),
     2IDEAL FAN POWER, EFFICIENCY 3F12.4)
C
      RETURN
      END
C
      FUNCTION FG1(X,N,XT,YT,IX)
C
```

```
      DIMENSICN XT(1),YT(1)
C
      IF (IX.LT.1) IX=1
      IF (IX.GT.N-1) IX=N-1
      I=SIGN(1.0,X-XT(IX))
 10   IF (IX.LT.1 .OR. IX.GE.N) GO TO 30
      IF (XT(IX).GT.X .OR. X.GT.XT(IX+1)) GO TO 20
      C=(X-XT(IX))/(XT(IX+1)-XT(IX))
      GC TO 100
 20   IX=IX+I
      GC TO 10
 30   C=IX/N
      IX=IX-I
 100  FG1=YT(IX)+C*(YT(IX+1)-YT(IX))
      RETURN
      END
C
      SUBROUTINE INCON (TIME)
C
      REAL*8 TICRD
      INTEGER ON
      CCMMON /AIR/ PINF,RHOINF,GAM,IQUIT
      CCMMON/AXIS/NXYS(26)
      CCMMON /BMCO / IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY
      CCMMON /COLUMN/ IVERT,ILATRL
      CCMMON /CONST/ PI,RAD,UO
      CCMMON /CNTRL/CONTW,CONTQ,CONTTH,QMULT,LCUVER,ACONTZ,ACONTW,ZEQUIL
     1 ,THEQL,ACBASE
      CCMMON /CURVE/NCURV(10)
      CCMMON/ENGINE/NPS,NPP,THSTS(25),THSTP(25),XP,YP,ZP,STHS,STHP,
     ATIF(25),TIS(25)
      CCMMCN /EQNCO/ NEQS,TCL(20),JQQ
      CCMMON /FAIR/ RHOA,XLAERO
      CCMMCN /FANMAP/QIN,QBFAN(25),QMFAN(25),QSFAN(25),ENBFAN,ENMFAN,
     1 ENSFAN,BRPM,EMRPM,SRPM,NPTSB,NPTSM,NPTSS
     2 ,PBFAN(25),PMFAN(25),PSFAN(25),TMEB(25),DELB(25),NB,TMES(25),
     3DETS(25),NS
      CCMMCN / FRCUDE / FN,FNCRIT
      CCMMCN/GBOW/ XBOW
      CCMMON /GEOM/     WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM
     1,DELS(4,10),XCP,ZCP
      CCMMCN /GEOMSW/ XAVG(10),DS
      CCMMCN/GRAF/NGRAF,NDRW
      CCMMON /HEADG/TICRD(6)
      CCMMCN /PWAVE/ FNCON,PWVCON
      CCMMON/LEAKER/ALEAK,BLEAK,CFSS,CFBS
      CCMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHC,NMASS,
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-            AMI(201),XI(201),YI(201),ZI(201),XS,ZS,HRHC              INCN0320
 COMMON /MATRIX/ A(6,6)                                               INCN0330
 COMMON /OPTION/ I3DOF,ISRGE,ITRIM,IDIA,IPITCH                        INCN0340
 COMMON /PLENUM/XLBW,XBBW,ABW,BUBHGT                                  INCN0350
 COMMON/PLVCCQ/NVI,NVD,NLI,NLD                                        INCN0360
 COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT                        INCN0370
 COMMON /PRTINT/ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,     INCN0380
-IRLD,IPROP,IAEROD,IRHS                                               INCN0390
 COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7     INCN0400
 COMMON /ROLL/ PHIMAX,TROLL                                           INCN0410
 COMMON/RUDDR/ NPR,DELRUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR,     INCN0420
ARCLB,RTC,RUCANG,TIR(25)                                              INCN0430
 COMMON /RISER/ AMPTC                                                 INCN0440
 COMMON/SOFTBS/XBF,PBS,SINBS,COSBS,XBS,ZBS,DELYBS,DPBS,ELMAXB,YAVG    INCN0450
1E(10),CENCAB                                                         INCN0460
 COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,DELYSS,DPSS              INCN0470
1 ,ELMAXS,YAVGS(10)                                                   INCN0480
 COMMON /SIDE/FXSW,FYSW,FZSW,FKSW,FMSW,FNSW,ALSW,YSW,XLSW,CFSW,CDSWINCN0490
1,VAREA   ,VCHORD,VSPAN,VANGLE,VCOS,VX,VY,VZ  ,AVBMSW,DELX,VTC        INCN0500
 COMMON/SLOPE/WATSLP,XPWV,XLXPWV,PWVHT,XPWVXS                         INCN0510
 COMMON /STABLE/ S(4),ISTAB                                           INCN0520
 COMMON /STSLR/ CPHI,CPHID                                            INCN0530
 COMMON /SUM/ ISUM1(8),ISUM2(8)                                       INCN0540
 COMMON / VALOLD / YOLD(20)                                           INCN0550
 COMMON /VARBLE/ VAL(40)                                              INCN0560
 COMMON /WAVE/ ETA(4,11),AW(10),CMEGA(10),DVCLW,NWAVE,BETA,           INCN0570
1                FXWAV,FYWAV,FZWAV,FKWAV,FMWAV,FNWAV                  INCN0580
2               ,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBBAR            INCN0590
 COMMON /WAVEF/WAVLEN(10),OMEGAE(10),WAVSLP(10),ENCPER(10)            INCN0600
 COMMON /WAVTAB/ NAL,DAL,SAL,NDS,DDS,SDS,NTH,DTH,STH,NBB,DBB,SBB,     INCN0610
1             AC1(20,5,7),AC2(20,5,7),AC3(20,5,7),AC4(20,5,7),        INCN0620
2             AC5(20,5,7),AC6(20,5,7),AC7(20,5,7)                     INCN0630
3            ,AC0(20,5,7),AC00(20,5,7),AC8(20,5,7),                   INCN0640
4             AS1(20,5,7),AS2(20,5,7),AS3(20,5,7),AS4(20,5,7),        INCN0650
5             AS5(20,5,7),AS6(20,5,7),AS7(20,5,7)                     INCN0660
6            ,AS0(20,5,7),AS00(20,5,7),AS8(20,5,7)                    INCN0670
7            ,BB(36),XREF,RX                                          INCN0680
 DIMENSION ZZZ(14050)                                                 INCN0690
 EQUIVALENCE (ZZZ,NAL)                                                INCN0700
 EQUIVALENCE                   (VAL(2),U),(VAL(3),V),(VAL(4),W),      INCN0710
1(VAL(5),P),(VAL(6),Q),(VAL(7),R),(VAL(8),PHI),(VAL(9),THETA),        INCN0720
2(VAL(10),Z),(VAL(11),BMASS),(VAL(21),X),(VAL(22),Y),(VAL(23),PSI),INCN0730
3(VAL(24),PB)                                                         INCN0740
 DIMENSION TEMP(7),XMO(10)                                            INCN0750
 DIMENSION TITLC(20)                                                  INCN0760
 DATA BEAM,BETAD,DELO,DELPI,DLRDO,DSO,ISYS,RMAXO,RCNO,RRATO,RREVO,    INCN0770
1 THETO,THSSI,TPRINO,UO,VXO,VZO,XBSI,XCPO,XLTOT,XPC,XRO,XSSI,YFO,     INCN0780
2 ZPC,ZRO,ZSSI/ 6*0.0,0,20*0.0/                                       INCN0790
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C                                                                        INCN0800
C       INITIAL CONDITIONS WITH WATSLP                                   INCN0810
C                                                                        INCN0820
        CC 9 I=1,8                                                       INCN0830
        ISUM1(I)=0                                                       INCN0840
      9 ISUM2(I)=0                                                       INCN0850
        PINF=2116.                                                       INCN0860
        RHCINF=.002378                                                   INCN0870
        GAM=1.4                                                          INCN0880
        ICLIT=600000
        GC TO 10                                                         INCN0890
 220C   READ(5,3000) NGRAF,NDRW                                          INCN0900
 3000   FCRMAT(2I2)                                                      INCN0910
        READ(5,3001) NXYS                                                INCN0920
 3001   FCRMAT(26I2)                                                     INCN0930
        READ(5,3002) TICRD                                               INCN0940
 3002   FCRMAT(6A8)                                                      INCN0950
10      READ(5,99) ISYSL,IOPT,(TEMP(I),I=1,7)                            INCN0960
        IF( ISYSL .EQ. ISYS .AND. ISYSL.EQ. 13) GOTC 70                  INCN0970
        ISYS=ISYSL                                                       INCN0980
        IF((ISYS.LE.0).OR.(ISYS.GT.22)) GO TO 70                         INCN0990
        GCTO(100,200,300,400,500,600,700,800,900,1000,1100,1200,1300,    INCN1000
       1140C,1500,1600,1700,1800,1900,2000,2100,220C),ISYS               INCN1010
C                                                                        INCN1020
C       PRCGRAM CONTROL PARAMETERS                                       INCN1030
C                                                                        INCN1040
100     CCNTINUE                                                         INCN1050
        GCTO(101,102,103,104,105,106,107),IOPT
 101    CCNTINUE                                                         INCN1070
        STIME=TEMP(1)                                                    INCN1080
        FTIME=TEMP(2)                                                    INCN1090
        DELC=TEMP(3)                                                     INCN1100
        DELPNT=TEMP(4)                                                   INCN1110
        TPRINO=TEMP(5)                                                   INCN1120
        IF (TPRINO.LT.STIME+DELPNT)  TPRINO = STIME+DELPNT               INCN1130
        IF (DELO.GT.DELPNT) DELO=DELPNT                                  INCN1140
        IF (DELC.EQ.0.0) GO TO 140                                       INCN1150
        GCTO 10                                                          INCN1160
 2000   READ(5,3003) NCURV                                               INCN1170
 3003   FCRMAT(10I1)                                                     INCN1180
        GC TO 10                                                         INCN1190
 210C   READ(5,2210) ISUM1                                               INCN1200
        READ(5,2210)ISUM2                                                INCN1210
 2210   FCRMAT(8I2)                                                      INCN1220
        GC TO 10                                                         INCN1230
102     READ (5,191) IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IRUD,  INCN1240
       1 IPROP,IAERCD,IRHS                                               INCN1250
        GCTO 10                                                          INCN1260
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103   READ (5,175) NEQS,JQQ,(TOL(J),J=1,NEQS)                        INCN1270
      GOTO 10                                                        INCN1280
 104  READ(5,191) IVERT,ILATRL,NVD,NVI,NLD,NLI                       INCN1290
      GO TO 10                                                       INCN1300
 105  CONTINUE                                                       INCN1310
      I3DOF=TEMP(1)                                                  INCN1320
      ISRGE=TEMP(2)                                                  INCN1330
      ITRIM=TEMP(3)                                                  INCN1340
      ICIA=TEMP(4)                                                   INCN1350
      IPITCH=TEMP(5)                                                 ********
      GO TO 10                                                       INCN1360
  106 CONTINUE                                                       INCN1370
      PRCMO1=TEMP(1)                                                 INCN1380
      PRCMO2=TEMP(2)                                                 INCN1390
      PRCMO3=TEMP(3)                                                 INCN1400
      PRCMO4=TEMP(4)                                                 INCN1410
      PRCMO5=TEMP(5)                                                 INCN1420
      PRCMO6=TEMP(6)                                                 INCN1430
      PRCMO7=TEMP(7)                                                 INCN1440
      GO TO 10                                                       INCN1450
107   CONTINUE                                                       INCN1451
      IF(TEMP(1).NE.0.)PINF=TEMP(1)                                  INCN1452
      IF(TEMP(2).NE.0.)RHOINF=TEMP(2)                                INCN1453
      IF(TEMP(3).NE.0.)GAM=TEMP(3)                                   INCN1454
      READ(5,2041) IQUIT                                             INCN1455
 2041 FORMAT(I10)                                                    INCN1456
      GOTO 10                                                        INCN1457
  140 WRITE(6,195)                                                   INCN1460
      STOP                                                           INCN1470
C                                                                    INCN1480
C     MASS DISTRIBUTION                                              INCN1490
C                                                                    INCN1500
  200 G=32.17                                                        INCN1510
      RHO=1.99                                                       INCN1520
      HRHO=RHO/2.                                                    INCN1530
      GO TO (210,220,230), IOPT                                      INCN1540
  210 IMM = 0                                                        INCN1550
      WEIGHT = TEMP(1)                                               INCN1560
      AM = WEIGHT/G                                                  INCN1570
      XS = TEMP(2)                                                   INCN1580
      ZS = TEMP(3)                                                   INCN1590
      AIXX = TEMP(4)                                                 INCN1600
      AIYY = TEMP(5)                                                 INCN1610
      AIZZ = TEMP(6)                                                 INCN1620
      AIXZ = TEMP(7)                                                 INCN1630
C                                                                    INCN1640
C     INERTIA MATRIX OPERATIONS                                      INCN1650
C                                                                    INCN1660
```

```
  212 DO 211 I=1,6
      DO 211 N=1,6
  211 A(I,N) = 0.0
      DO 213 N=1,3
  213 A(N,N)=AM
      A(4,4)=AIXX
      A(5,5)=AIYY
      A(6,6)=AIZZ
      A(4,6)=-AIXZ
      A(6,4)=-AIXZ
      AIMAX=AMAX1(AM,AIXX,AIYY,AIZZ,ABS(AIXZ))
      DO 214 I=1,6
      DO 214 J=1,6
  214 A(I,J)=A(I,J)/AIMAX
C
      CALL DMINV (A,6,D)
C
      DO 215 I=1,6
      DO 215 J=1,6
  215 A(I,J)=A(I,J)/AIMAX
      IF (D.NE.0.0) GO TO 10
      WRITE (6,216)
      STOP
C
C     READ WEIGHT DISTRIBUTION - ASSUME TRANSVERSE (PORT/STBD) SYMMETRY
C        X INPUT DIST. FWD. OF (SIDEWALL) TRANSOM
C        Y INPUT DIST. TO STARBOARD
C        Z INPUT DIST. UP FROM KEEL-LINE
C
  220 I = 1
  222 READ (5,192) AMI(I),XI(I),YI(I),ZI(I)
      IF (AMI(I).LT.0.0)  GO TO 224
      I = I+1
      IF ( I.GT.201 )  GO TO 70
      GO TO 222
  224 NMASS = I-1
      SUM = 0.0
      SUX = 0.0
      SUZ = 0.0
      DO 225 I=1,NMASS
      AMI(I) = AMI(I)/G
      SUM = SUM+AMI(I)
      SUX = SUX+AMI(I)*XI(I)
  225 SUZ = SUZ+AMI(I)*ZI(I)
      AM = SUM*2.0
      WEIGHT = AM*G
      ZS  = SUZ/SUM
      XS  = SUX/SUM
```

```
      SUM = 0.0                                                         INCN2150
      SUX = 0.0                                                         INCN2160
      SUY = 0.0                                                         INCN2170
      SUZ = 0.0                                                         INCN2180
      DO 226 I=1,NMASS                                                  INCN2190
      XI(I) = XI(I)-XS                                                  INCN2200
      ZI(I) = -ZI(I)+ZS                                                 INCN2210
      AMK = AMI(I)*2.0                                                  INCN2220
      SUX = SUX+AMK*XI(I)*XI(I)                                         INCN2230
      SUY = SUY+AMK*YI(I)*YI(I)                                         INCN2240
      SUZ = SUZ+AMK*ZI(I)*ZI(I)                                         INCN2250
  226 SUM = SUM+AMK*XI(I)*ZI(I)                                         INCN2260
      AIXX = SUY+SUZ                                                    INCN2270
      AIYY = SUX+SUZ                                                    INCN2280
      AIZZ = SUX+SUY                                                    INCN2290
      AIXZ = SUM                                                        INCN2300
      GO TO 212                                                         INCN2310
  230 GO TO 10                                                          INCN2320
C                                                                       INCN2330
C     XX AND YY TABLES                                                  INCN2340
C                                                                       INCN2350
300   CONTINUE                                                          INCN2360
      NSTA(1) = TEMP(1)                                                 INCN2370
      NSTA(2) = TEMP(2)                                                 INCN2380
      NSTA(3) = TEMP(3)                                                 INCN2390
      NSTA(4) = TEMP(4)                                                 INCN2400
      XLTOT=TEMP(5)                                                     INCN2410
      GOTO 10                                                           INCN2420
C                                                                       INCN2430
C     SIDEWALL (INCLUDING APPENDAGES)                                   INCN2440
C                                                                       INCN2450
400   CONTINUE                                                          INCN2460
      GOTO (401,402),IOPT                                               INCN2470
401   YSW=TEMP(1)                                                       INCN2480
      XLSW=TEMP(2)                                                      INCN2490
      CFSW=TEMP(3)                                                      INCN2500
      CDSW=TEMP(4)                                                      INCN2510
      AVBMSW=TEMP(5)                                                    INCN2520
      READ (10) ZZZ                                                     INCN2530
      REWIND 10                                                         INCN2540
      GOTO 10                                                           INCN2550
C                                                                       INCN2560
C    BLOCK 4 OPTION 2 REMOVED.       NO APENDAGES                       INCN2570
C                                                                       INCN2580
  402 CONTINUE                                                          INCN2590
      GOTO 10                                                           INCN2600
C                                                                       INCN2610
C     STERNSEAL                                                         INCN2620
```

```
C
500     CCNTINUE
        XSSI=TEMP(1)
        ZSSI=TEMP(2)
        ALEAK=TEMP(3)
        CFSS=TEMP(4)
        ELMAXS = TEMP(5)
        DFSS=TEMP(6)
        XLF=TEMP(7)
        ARGA = ELMAXS/XLF
        CCSTH = ARGA
        THSSI = ARCCS(ARGA)
        SINTH = SIN(THSSI)
        GC TO 10
C
C       BCWSEAL
C
 600    GC TO(610,620),IOPT
 61C    CCNTINUE
        XBSI=TEMP(1)
        CFBS=TEMP(2)
        CFBS=TEMP(3)
        ZBSI=TEMP(4)
        ELMAXB = TEMP(5)
        XEF=TEMP(6)
        BLEAK=TEMP(7)
        GCTO 10
 620    CENCAB=TEMP(1)
        GC TO 10
C
C       PLENUM
C
700     CCNTINUE
        GC TO (705,710),IOPT
 705    CCNTINUE
        XLBW=TEMP(1)
        XEBW=TEMP(2)
        XPWV=TEMP(3)
        WIDTH=TEMP(4)
        XL=TEMP(5)
        XCPC=TEMP(6)
        BUBHGT=TEMP(7)
        XLXPWV=XLBW-XPWV
        PWVHT=(XPWV*XPWV-XLXPWV*XLXPWV)*.5/XL
        XPWVXS=XPWV-XS
        ABW=XBBW*XLBW
        AB=WIDTH*XL
        VCLNOM=(ABW+AB)*BUBHGT/2.
```

```
      GOTO 10                                                           INCN3110
  710 CONTINUE                                                          INCN3120
      FACRIT=TEMP(1)                                                    INCN3130
      GO TO 10                                                          INCN3140
C                                                                       INCN3150
C     PROPULSION                                                        INCN3160
C                                                                       INCN3170
800   CONTINUE                                                          INCN3180
      GO TO (805,810),IOPT                                              INCN3190
  805 CONTINUE                                                          INCN3200
      XFO=TEMP(1)                                                       INCN3210
      YFO=TEMP(2)                                                       INCN3220
      ZFO=TEMP(3)                                                       INCN3230
      GO TO 10                                                          INCN3240
C                                                                       INCN3250
C BLOCK 8 OPTION 2 REMOVED. ENGINE OUT INPUT IN BLOCK 16                INCN3260
C                                                                       INCN3270
  810 CONTINUE                                                          INCN3280
      GOTO 10                                                           INCN3290
C                                                                       INCN3300
C     RUDDER                                                            INCN3310
C                                                                       INCN3320
900   CONTINUE                                                          INCN3330
      GO TO (905,910,915),IOPT                                          INCN3340
  905 XRO = TEMP(1)                                                     INCN3350
      YR=TEMP(2)                                                        INCN3360
      ZRO = TEMP(3)                                                     INCN3370
      RSPAN=TEMP(4)                                                     INCN3380
      RASPR=TEMP(5)                                                     INCN3390
      RAREA=TEMP(6)                                                     INCN3400
      RCLB=2.*PI*RASPR/(RASPR+3.)                                       INCN3410
      RTC=TEMP(7)                                                       INCN3420
      GO TO 10                                                          INCN3430
C                                                                       INCN3440
C     910 NOT USED                                                      INCN3450
C                                                                       INCN3460
  910 CONTINUE                                                          INCN3470
      GO TO 10                                                          INCN3480
  915 CONTINUE                                                          INCN3490
      GOTO 10                                                           INCN3500
C                                                                       INCN3510
C     AERODYNAMICS                                                      INCN3520
C                                                                       INCN3530
1000  CONTINUE                                                          INCN3540
      XLAERO=TEMP(1)                                                    INCN3550
      BEAM=TEMP(2)                                                      INCN3560
      RHOA=.5*RHOINF*XLAERO*BEAM                                        INCN3570
      GOTO 10                                                           INCN3580
```

```
C                                                                       
C      WAVES                                                            
C                                                                       
 1100  CONTINUE                                                         
       IWAVSW=IOPT                                                      
       IF(IWAVSW.GT.4) GO TO 70                                         
       NWAVE=TEMP(1)                                                    
       IF(NWAVE .EQ. 0) GOTO 10                                         
       IF(NWAVE .GT. 10) GOTO 70                                        
       BETAD=TEMP(2)                                                    
       BETA=BETAD/RAD                                                   
       COSBET=COS(BETA)                                                 
       SINBET=SIN(BETA)                                                 
       TC = 1.0                                                         
       GO TO (1104,1106,1108,1108),IWAVSW                               
 1104  DO 1105 I=1,NWAVE                                                
 1105  READ(5,1190) OMEGA(I),AW(I)                                      
       GOTO 10                                                          
 1106  DO 1107 I=1,NWAVE                                                
 1107  READ (5,1190) WAVLEN(I) ,AW(I)                                   
       GOTO 10                                                          
  1108 SHTWV=TEMP(3)                                                    
       G1G=32.17                                                        
       G2=G1G*G1G                                                       
       G4=G2*G2                                                         
       GOTO(10,10,1110,1111),IWAVSW                                     
  1110 CONTINUE                                                         
       PERL=TEMP(4)                                                     
       PERH=TEMP(5)                                                     
       WWN=(2.0*3.141592)*(1.0/PERH)                                    
       WWX=(2.0*3.141592)*(1.0/PERL)                                    
       GO TO 1112                                                       
  1111 CONTINUE                                                         
       WWN = TEMP(4)                                                    
       WWX = TEMP(5)                                                    
  1112 CONTINUE                                                         
       UUU=SQRT(SHTWV/0.0185)*1.6878                                    
       UU4=UUU**4.                                                      
       CCC=(WWX/WWN)**(1./NWAVE)                                        
       WWPO =WWN                                                        
       DO 1113 I = 1,NWAVE                                              
       WWPN = WWPO*CCC                                                  
       WW =(WWPN+WWPO)/2                                                
       DDW = WWPN-WWPO                                                  
       WWPO  = WWPN                                                     
       WW4= WW**4.0                                                     
       WW5 = WW**5.0                                                    
       SS = 0.0081*G2/(EXP(0.74*G4/(WW4*UU4))*WW5)                      
```

```
      OMEGA(I) =WW                                                        INCN4070
      AW(I) = SQRT(2.*SS*DDW)                                             INCN4080
 1113 CONTINUE                                                            INCN4090
      GO TO 10                                                            INCN4100
C                                                                         INCN4110
C     INITIAL CONDITIONS                                                  INCN4120
C                                                                         INCN4130
1200  CONTINUE                                                            INCN4140
      UO = TEMP(1)                                                        INCN4150
      THETO = TEMP(2)                                                     INCN4160
      DSO = TEMP(3)                                                       INCN4170
      DELPI=TEMP(4)                                                       INCN4180
      DPHI = TEMP(5)                                                      INCN4190
      GO TO 10                                                            INCN4200
1300  CONTINUE                                                            INCN4210
C                                                                         INCN4220
C     INPUT COMPLETED. 1) PRINT ALL INPUT                                 INCN4230
C                                                                         INCN4240
      WRITE(6,2004) TITLC                                                 INCN4250
      WRITE(6,2030) PINF,RHOINF,GAM                                       INCN4251
      WRITE (6,2001) STIME,FTIME,DELO,TPRINO,DELPNT                       INCN4260
      WRITE (6,2002) IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,IRUD,INCN4270
     1 IFROP,IAERCD,IRHS                                                  INCN4280
      WRITE(6,2021) I3DOF,ISRGE,ITRIM,ICIA                                INCN4290
      WRITE (6,2029) PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7     INCN4300
      WRITE (6,2003) NEQS, (TOL(J),J=1,NEQS)                              INCN4310
      WRITE (6,219) WEIGHT,XS,ZS,AIXX,AIYY,AIZZ,AIXZ                      INCN4320
      WRITE(6,217)A,AIMAX                                                 INCN4330
      WRITE (6,2018) NSTA                                                 INCN4340
      WRITE (6,490) YSW,XLSW,CFSW,CDSW,VANGLE,VSPAN,VCHCRD,VXO,VY,VZO,    INCN4350
     1 AVBMSW,VTC                                                         INCN4360
      WRITE (6,491) NAL,DAL,SAL,NDS,DDS,SDS,NTH,DTH,STH,NBB,DBB,SBB       INCN4370
      IF (IMM.GT.0)  WRITE(6,1549)    (XMO(J),J=1,IMNX)                   INCN4380
      WRITE (6,1519) IMM,IMNX,IMNY,IBMFIL,BTIME,INT                       INCN4390
      IF (IMM.GT.0)  WRITE(6,1559) (YMI(J),J=1,IMNY)                      INCN4400
      WRITE (6,2010) XLBW,XBBW                                            INCN4410
      WRITE (6,2011) XL,WIDTH,XCPO,VOLNOM,BUBHGT                          INCN4420
      WRITE (6,2020) DELPI                                                INCN4430
      WRITE(6,2009) FNCRIT,XLTOT                                          INCN4440
      WRITE (6,2028) ENBFAN,BRPM,ENMFAN,EMRPM,ENSFAN,SRPM                 INCN4450
      WRITE (6,2013) XRO,YR,ZRO,RONO,RMAXO,RRATO,RREVO,DLRDO              INCN4460
     1 ,RSPAN,RASPR,RAREA,RCLB,RTC                                        INCN4470
      WRITE (6,2012)          XPO,YPO,ZPO                                 INCN4480
      WRITE (6,2027) XLAERO,BEAM                                          INCN4490
      WRITE (6,2026) XBSI,CFBS,DPBS,ELMAXB                                INCN4500
      WRITE (6,2025) XSSI,ZSSI,ALEAK,CFSS,ELMAXS,CPSS,XLF                 INCN4510
      WRITE (6,2017) UO,THETO,DSO                                         INCN4520
C                                                                         INCN4530
```

```
C                 AND 2) INITIALIZE VARIABLES FOR CALCS.
C
      DO 1302 I=1,40
 1302 VAL(I) = 0.0
      U = UO*1.6889
      XSS=-(XS-XSSI)
      ZSS=ZS-ZSSI
      THETA = THETO/RAD
      PHI = CPHI/RAD
      THEQL=THETA
      DS = DSC/12.
      Z=-ZS+DS
      ZEQUIL=Z
      PHIMAX=0.
      TROLL=0.
      IRDS=0
      TL=0.0
C
C     WAVE PARAMETERS TABLE
C
      IF(NWAVE .EQ.0) GOTO 1321
      AMPTC=1.30287
      GOTO(1310,1315),IWAVSW
 1310 DO 1311 I=1,NWAVE
 1311 WAVLEN(I)=2.*PI*G/(OMEGA(I)*OMEGA(I))
      GOTO 1317
 1315 DO 1316 I=1,NWAVE
 1316 OMEGA(I)=SQRT(2.*PI*G/WAVLEN(I))
 1317 CONTINUE
C
C     CALCULATE INITIAL FREQUENCIES OF ENCOUNTER
C
      DO 1318 I=1,NWAVE
      WAVSLP(I) = 360.0*AW(I)/WAVLEN(I)
      OMEGAE(I) =2.*PI*(SQRT(G*WAVLEN(I)/(2.*PI))-U*COSBET)/WAVLEN(I)
      ENCPER(I) = 2.0*PI/OMEGAE(I)
 1318 CONTINUE
      WRITE (6,1191) NWAVE,BETAD,(OMEGA(I),OMEGAE(I),WAVLEN(I),AW(I),
     1                WAVSLP(I),ENCPER(I),I=1,NWAVE)
      GOTO 1322
 1321 WRITE (6,1192)
 1322 CONTINUE
      DO 1303 I=1,4
      DO 1303 N=1,11
 1303 ETA(I,N) = 0.0
      DVCLW = 0.0
      FXWAV = 0.0
      FYWAV = 0.0
```

```
      FZWAV = 0.0                                                   INCN5020
      FXWAV = 0.0                                                   INCN5030
      FMWAV = 0.0                                                   INCN5040
      FNWAV = 0.0                                                   INCN5050
      ZBAR=Z                                                        INCN5060
      PHIBAR=PHI                                                    INCN5070
      THEBAR=THETA                                                  INCN5080
      TIME=STIME                                                    INCN5090
      DELT = DELO                                                   INCN5100
      TPRINT=TPRINO-DELPNT                                          INCN5110
      PWVCON=4.*WEIGHT/(RHO*G*XLBW)                                 INCN5120
      FNCON=SQRT(XLBW*G)                                            INCN5130
      VX=VXO-XS                                                     INCN5140
      VZ = ZS-VZO                                                   INCN5150
      XP=XPO-XS                                                     INCN5160
      XR = XRO-XS                                                   INCN5170
      YP=YPO                                                        INCN5180
      ZP=ZS-ZPO                                                     INCN5190
      ZR = ZS-ZRO                                                   INCN5200
      IF (IMM.EQ. 0) GO TO 1305                                     INCN5210
      DO 1304 J=1,IMNX                                              INCN5220
 1304 XMI(J) = XMO(J) - XS                                          INCN5230
 1305 CONTINUE                                                      INCN5240
      XCP = XCPO-XS                                                 INCN5250
      ZCP = ZS-BUBHGT                                               INCN5260
      XBS=XBSI-XS                                                   INCN5270
      N=NSTA(3)                                                     INCN5280
      ZBS=ZS-ZBSI                                                   INCN5290
      DO 1364 J=1,N                                                 INCN5300
      DELYBS=XBBW/(N-1)                                             INCN5310
       XX(3,J)=XBS-XSSI                                             INCN5320
      YY(3,J)=-0.5*XBBW+(J-1)*DELYBS                                INCN5330
 1364 CONTINUE                                                      INCN5340
      N=N-1                                                         INCN5350
      DO 1367 J=1,N                                                 INCN5360
      YAVGB(J)=(YY(3,J+1)+YY(3,J))/2.                               INCN5370
 1367 CONTINUE                                                      INCN5380
      N=NSTA(4)                                                     INCN5390
      DELYSS=XBBW/(N-1)                                             INCN5400
      DO 1365 J=1,N                                                 INCN5410
      XX(4,J)=-XS                                                   INCN5420
      YY(4,J)=-.5*XBBW+(J-1)*DELYSS                                 INCN5430
 1365 CONTINUE                                                      INCN5440
      N=N-1                                                         INCN5450
      DO 1368 J=1,N                                                 INCN5460
      YAVGS(J)=(YY(4,J+1)+YY(4,J))/2.                               INCN5470
 1368 CONTINUE                                                      INCN5480
      XBOW=XLTOT-XS                                                 INCN5490
```

```
      N=NSTA(1)
      DELX=XBSI/(N-1)
      DO 1309 J=1,2
      DO 1309 I=1,N
      XX(J,I)=(I-1)*DELX-XS
 1309 YY(J,I)= YSW*(2*J-3)
      WRITE(6,1366) ((XX(J,N),N=1,11),(YY(J,N),N=1,11),J=1,4)
 1366 FORMAT (//17H XX AND YY ARRAYS /14H PORT SIDEWALL /2(11F10.2/),
     1 15H STBD. SIDEWALL /2(11F10.2/),9H BOW SEAL /2(11F10.2/),
     2 11H STERN SEAL /2(11F10.2/))
      N=NSTA(1)-1
      DO 1308 I=1,N
 1308 XAVG(I)=DELX*(2*I-1)/2.-XS
C
      CALL WAVES(TIME)
C
C     INITIALIZE BUBBLE PRESSURE, ABSOLUTE (PSF)
C
      PE=PINF+DELPI
      PEBAR=DELPI
      PBAR=DELPI
      PSS=PB+DPSS
      PBS=PB+DPBS
      AB=ABW-(ABW-AB)*(ZS+Z/BUBHGT)
      CF=.37/((U/FNCON)**1.5655981)
      WATSLP=PBBAR*CF*PWVCON/WEIGHT
      IF (IDIA.EQ.1) GO TO 6
      VOL=VOLNOM-.5*(AB+ABW)*(Z+ZS)-DVCLW
     1+.5*WATSLP*XL*AB
      GO TO 7
    6 VOL=VOLNOM-.5*(AB+ABW)*(Z+ZS)-DVCLW+PBAR*.3175333
    7 CONTINUE
      BMASS=(PB/PINF)**(1./GAM)*VOL*RHOINF
      WRITE (6,2023)
      RETURN
C
C     RUN TERMINATOR
C
 1400 WRITE(6,98)
      STOP
C
C     BENDING MOMENT
C
 1500 GO TO (1510,1520,1530,1540), IOPT
 1510 IMM = TEMP(1)
      IF (IMM.GT.3)  GO TO 70
      IMNX = TEMP(2)
      IF (IMNX.GT.10)  GO TO 70
```

```
      IMNY = TEMP(3)
      IF (IMNY.GT.7)  GO TO 70
      IBMFIL = TEMP(4)
      BTIME = TEMP(5)
      IF (IMM.EQ.3)  IMT = TEMP(6)
      GO TO 10
 1520 DO 1521 J=1,7
 1521 XMO(J) = TEMP(J)
      IF (IMNX.LE.7)  GO TO 10
      READ 1522, (XMO(J),J=8,IMNX)
      GO TO 10
 1530 DO 1531 J=1,IMNY
 1531 YMI(J) = TEMP(J)
      GO TO 10
 1540 CONTINUE
      GO TO 10
1600  CONTINUE
      GO TO(1605,1610,1615),IOPT
 1605 CONTINUE
C
C   VALUES INPUT FOR STBD SCREW
C
      THST1=TEMP(1)
      NPS=TEMP(2)
      STHS=TEMP(3)
      IF(NPS.EQ.0.0) GO TO 1609
      READ(5,1950)(TIS(J),J=1,NPS)
      READ(5,1950)(THSTS(J),J=1,NPS)
      GO TO 10
 1609 THSTS(1)=THST1
 1610 CONTINUE
C
C   VALUES INPUT FOR PORT SCREW
C
      THST2=TEMP(1)
      NPP=TEMP(2)
      STHP=TEMP(3)
      IF(NPP.EQ.0.0) GO TO 1614
      READ(5,1950)(TIP(J),J=1,NPP)
      READ(5,1950)(THSTP(J),J=1,NPP)
      GO TO 10
 1614 THSTP(1)=THST2
 1615 CONTINUE
C
C   VALUES INPUT FOR RUDDER
C
      DELR=TEMP(1)
      NPR=TEMP(2)
```

```
      IF(NPR.EQ.0.0) GO TO 1616
      READ(5,1950)(TIR(J),J=1,NPR)
      READ(5,1950)(DELRUD(J),J=1,NPR)
      GO TO 10
 1616 DELRUD(1)=DELR
      GO TO 10
 1700 GO TO (1705,1710),IOPT
 1705 NB=TEMP(1)
      READ(5,1950)(TMEB(I),I=1,NB)
      READ(5,1950)(DELB(I),I=1,NB)
      GO TO 10
 1710 NS=TEMP(1)
      READ(5,1950)(TMES(I),I=1,NS)
      READ(5,1950)(DETS(I),I=1,NS)
      GOTO 10
C
C     TITLE CARD (ALL 80 COLUMNS )
C
 1800 READ  (5,2022)  TITLC
      GO TO 10
C
C     FAN MAPS
C
1900  CONTINUE
      GO TO (1905,1910,1915),IOPT
1905  CONTINUE
      ENBFAN=TEMP(1)
      BRPM=TEMP(2)
      NPTSB=TEMP(3)
      READIN=TEMP(4)
      IF (READIN .EQ. 0.0) GO TO 10
      READ (5,1950) (PBFAN(J),J=1,NPTSB)
      READ (5,1950) (QBFAN(J),J=1,NPTSB)
      GO TO 10
1910  CONTINUE
      ENMFAN=TEMP(1)
      EMRPM=TEMP(2)
      NPTSM=TEMP(3)
      READIN=TEMP(4)
      IF (READIN .EQ. 0.0) GO TO 10
      READ (5,1950) (PMFAN(J),J=1,NPTSM)
      READ (5,1950) (QMFAN(J),J=1,NPTSM)
      GO TO 10
1915  CONTINUE
      ENSFAN=TEMP(1)
      SRPM=TEMP(2)
      NPTSS=TEMP(3)
      READIN=TEMP(4)
```

```
      IF (READIN .EQ. 0.0) GO TO 10                                     INCN6940
      READ (5,1950) (PSFAN(J),J=1,NPTSS)                                INCN6950
      READ (5,1950) (QSFAN(J),J=1,NPTSS)                                INCN6960
      GO TO 10                                                          INCN6970
 1950 FORMAT(8F10.0)                                                    INCN6980
C                                                                       INCN6990
C     ERROR IN INPUT                                                    INCN7000
C                                                                       INCN7010
   70 CONTINUE                                                          INCN7020
      WRITE (6,79) ISYS                                                 INCN7030
      STOP                                                              INCN7040
C                                                                       INCN7050
   79 FORMAT(34H INPUT ERROR - - - STOP - -  ISYS= ,I3)                 INCN7060
   98 FORMAT(1H1,20(/),50X,19H COMPLETED ALL RUNS )                     INCN7070
99    FORMAT(I3,I2,7F10.0)                                              INCN7080
  191 FORMAT (16I5)                                                     INCN7090
  192 FORMAT (5F10.0)                                                   INCN7100
  195 FORMAT(///10X,65HERROR IN INPUT --- DELT AND/OR DELPNT EQUALS ZEROINCN7110
     1 --- JOB ABORTED )                                                INCN7120
  175 FORMAT (2I2/(8F10.0))                                             INCN7130
  216 FORMAT(///10X,82HERROR IN INPUT --- INPUT INERTIA ELEMENTS LEAD TOINCN7140
     1 ZERO DETERMINANT --- JOB ABORTED )                               INCN7150
  217 FORMAT(22H INERTIA MATRIX, AIMAX  6E15.4/(22X,6E15.4))            INCN7160
  219 FORMAT(30H WEIGHT, C.G., INERTIA MOMENTS 7F12.3)                  INCN7170
  305 FORMAT ( 11F7.0 )                                                 INCN7180
  490 FORMAT(15H SIDEWALL INPUT 12(F8.3,1X))                            INCN7190
  491 FORMAT(26H SIDEWALL TABLE PARAMETERS 4(I4,F7.3,F7.3))             INCN7200
 1190 FORMAT(2F10.0)                                                    INCN7210
 1191 FORMAT(/12H0NO OF WAVES I2,10H BETA(DEG)F5.0/15H OMEGA(RAD/SEC) , INCN7220
     15X,16H OMEGAE(RAD/SEC) 5X,16H WAVE LENGTH(FT) 5X,14H AMPLITUDE(FT)INCN7230
     - 5X,16HMAX  SLOPE (DEG)5X,13HPERIOD,E(SEC)/(F8.4,12X,F8.4,4F20.3))INCN7240
 1192 FORMAT(/11H0CALM WATER)                                           INCN7250
 1519 FORMAT(32H0MOMENT CALC. CONTROL PARAMETERS 4I5, F8.3, I5 )        INCN7260
 1522 FORMAT ( 5X,7F10.0)                                               INCN7270
 1549 FORMAT(22H MOMENT CALCS. AT X OF 11F10.3)                         INCN7280
 1559 FORMAT(22H MOMENT CALCS. AT Y OF 11F10.3)                         INCN7290
 2004 FORMAT(33H1SES MOTIONS AND LOADS PROGRAM - 20A4,/)                INCN7300
 2001 FORMAT(23H START AND FINISH TIMES 2F10.2/                         INCN7310
     -22H INITIAL TIME INTERVAL F12.4/                                  INCN7320
     -18H START PRINTING AT F8.2,17H IN INCREMENTS OF F8.2)             INCN7330
 2002 FORMAT(24H INTERMEDIATE PRINT TAGS 16I5)                          INCN7340
 2003 FORMAT(39H NO. OF STATE EQUATIONS, AND TOLERANCESI5/(10X,10E12.2))INCN7350
 2009 FORMAT(23H0CRITICAL FROUDE NUMBER F15.4,5X,19H TOTAL CRAFT LENGTH INCN7360
     1      F15.4)                                                      INCN7370
 2010 FORMAT(34H0PLENUM, LENGTH AND WIDTH AT WATER 2F12.4)              INCN7380
 2011 FORMAT(34H PLENUM, LENGTH AND WIDTH AT HULL  2F12.4/              INCN7390
     -      35H PLENUM, CENTER OF PRESSURE AT HULL F12.4/               INCN7400
     -23H PLENUM, NOMINAL VOLUME F12.1,10X, 6HHEIGHT F12.4)             INCN7410
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 2012 FORMAT(/33H PROPULSION, X, Y, Z COORDINATES  3F12.4/)
 2013 FORMAT(/28H0RUDDER, X, Y, Z COORDINATES  3F12.4/
     -        41H RUDDER, ON, MAX, RATE, REVERSE, INITIAL  5F12.4/
     -        33H RUDDER,SPAN,ASPECT,AREA,CLB,T/C  5F12.4)
 2017 FORMAT(/39H0INITIAL CONDITIONS, VELOCITY (KNOTS) = F7.2, 5X,
     -        13HPITCH (DEG) = F8.3,5X,12HDRAFT (IN) = F8.2)
 2018 FORMAT( 49H NUMBER OF STATIONS, SIDEWALLS (F+S), SEALS (B+S) ,4I5)
 2020 FORMAT( 38H PLENUM, INITIAL PRESSURE, GAGE (PSF)  F8.2)
 2021 FORMAT(79H PROGRAM OPTION SWITCH SETTINGS (LATERAL PLANE,CONSTANT
     -SPEED,TRIM,MEMBRANE)      7I5)
 2022 FORMAT (20A4 )
 2023 FORMAT ( 1H1 )
 2025 FORMAT( 16H STERNSEAL INPUT  7F12.4 )
 2026 FORMAT( 16H BOWSEAL INPUT     7F12.4 )
 2027 FORMAT( 19H0AERODYNAMICS INPUT  7F12.4)
 2028 FORMAT( 33H0FANS, NO. + RPM, BOW,MAIN,STERN  3(F10.0,F10.1))
 2029 FORMAT(32H PROGRAM MODIFICATION SETTINGS        7(F12.4,1X))
 2030 FORMAT(' PINF =',F8.2,5X,'RHOINF =',F10.7,5X,'GAM = ',F8.2/)
      END
C
      SUBROUTINE INTGRL (TIME)
C
      INTEGER ON
      COMMON /BMCO / IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY
      COMMON /EQNCO/ NEQS,TOL(20),JQQ
      COMMON /KSWTCH/ ITHRST
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,
     -                AMI(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO
      COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7
      COMMON /PRTINT/ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,
     -IRUD,IPROP,IAEROD,IRHS
      COMMON /STABLE/ S(4),ISTAB
      COMMON/STEP/STEP2
      COMMON / VALOLD / YOLD(20)
      COMMON /VARBLE/ VAL(40)
      EQUIVALENCE (VAL(1),X),(VAL(2),Y(1))
      DIMENSION Y(20),ERROR(20)
      REAL K1(20),K2(20),K3(20),K4(20),K5(20)
      DATA IPASS/0/
C
      STEP2=1.0
      PB=VAL(24)
      BMASS=Y(10)
    1 IF((TIME+DELT).LE.TPRINT) GO TO 12
      DEL=DELT
      DELT=TPRINT-TIME
```

```
      IPASS=1
   12 X=TIME
      DO 2 J=1,NEQS
      Y(J)=YOLD(J)
    2 CONTINUE
      IFIRST=1
C
      CALL RHS(K1)
C
      IFIRST=2
      INT = 0
      IF (IACCEL.NE. ON) GO TO 14
      ACCLAT = (K1(2)+Y(1)*Y(6))/G
      WRITE  (6,101)  ACCLAT , DELT
  14  CN=2
   15 H=DELT/3.
      X=TIME+H
      DO 3 J=1,NEQS
    3 Y(J)=YOLD(J)+H*K1(J)
C
      CALL RHS(K2)
C
      DO 4 J=1,NEQS
    4 Y(J)=YOLD(J)+.5*H*(K1(J)+K2(J))
C
      CALL RHS(K3)
C
      X=TIME+.5*DELT
      DO 5 J=1,NEQS
    5 Y(J)=YOLD(J)+.375*H*(K1(J)+3.*K3(J))
C
      CALL RHS(K4)
C
      X=TIME+DELT
      DO 6 J=1,NEQS
    6 Y(J)=YOLD(J)+.5*H*(3.*K1(J)-9.*K3(J)+12.*K4(J))
C
      CALL RHS(K5)
C
      IF (JCQ.EQ. 1 ) GO TO 7
      DO 7 J=1,NEQS
      ERROR(J)=(K1(J)-4.5*K3(J)+4.*K4(J)-.5*K5(J))*H/5.0
      IF(ABS(ERROR(J)).GT.TOL(J)) GO TO 11
    7 CONTINUE
      DO 105 J=1,NEQS
      Y(J)=YOLD(J)+.5*H*(K1(J)+4.*K4(J)+K5(J))
  105 YOLD(J)=Y(J)
      TIME=TIME+DELT
```

```
      IF (IPASS.EQ.1) GO TO 8
      IF (JCQ.EQ. 1 ) GO TO 10
      DC 75 J=1,NEQS
      IF(ABS(ERROR(J)).GT.TOL(J)/16.) GO TO 9
   75 CCNTINUE
      DELT=2.*DELT
      IF (DELT.GT.DELPNT) DELT=DELPNT
C
   1C RETURN
C
    9 STEP2=DELT
      GC TO 1C
    8 CELT=DEL
      IPASS=0
      GC TO 10
   11 CELT=DELT/2.
      IF (DELT.LT. 1.E-6 )  GO TO 25
      IF(JQQ.EQ.2) GO TO 26
                         WRITE (6,666) TIME,DELT,J,ERROR(J),TOL(J)
   27 IPASS=0
      GC TO 15
   26 STEP1=DELT*2.0
      IF(STEP1.LT.STEP2)STEP2=STEP1
      GC TO 27
   25 WRITE ( 6,150 )
      WRITE (6,100) TIME,DELT,(K1(J),J=1,NEQS),VAL
      CALL COLFIL
      STCP
C
  100 FCRMAT(/10X,23HINTGRL TIME,DELT,K1,VAL /2E15.4/2(5E15.4/),5(8E15.4
     1/))
  101 FCRMAT(1H0,9X,33HTCTAL LATERAL ACCELERATION (G) =    F12.4,
     112X,5HDT =  E15.4)
  150 FORMAT(1H1,10X,44HDELTA TIME LESS THAN 1.0E-6  -  -   JOB STOPS )
  666 FCRMAT(/10X,5HINT-J 2E30.5,I5,2E20.5)
      END
C
      SLBROUTINE PROP
C
      INTEGER ON
      CCMMON /CONST/ PI,RAD,UO
      CCMMON /FPROP/ FX,FY,FZ,FK,FM,FN
      CCMMON/ENGINE/NPS,NPP,THSTS(25),THSTP(25),XP,YP,ZP,STHS,STHP,
     ATIP(25),TIS(25)
      CCMMCN /PRTINT/ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBCWSL,ISTNSL,IWAVES,
     -IRUC,IPROP,IAEROD,IRHS
      CCMMCN /PROMOD/ PROMO1,PROMO2,PROMO3,PROMC4,PROMO5,PROMO6,PROMO7
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```
      COMMON/RUDDR/ NPR,DELRUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR,  PROP0120
     ARCLB,RTC,RUDANG,TIR(25)                                           PROP0130
      COMMON /VARBLE/ VAL(40)                                           PROP0140
      EQUIVALENCE (VAL(1),TIME),(VAL(2),U),(VAL(3),V),(VAL(4),W),       PROP0150
     1(VAL(5),P),(VAL(6),Q),(VAL(7),R),(VAL(8),PHI),(VAL(9),THETA),     PROP0160
     2(VAL(10),Z),(VAL(11),BMASS),(VAL(21),X),(VAL(22),Y),(VAL(23),PSI),PROP0170
     3(VAL(24),PB)                                                      PROP0180
      DIMENSION THS(1),THP(1),TS(1),TP(1),RUD(1),TR(1)                  PROP0190
      EQUIVALENCE (THSTS(1),THS(1)),(THSTP(1),THP(1)),(TIS(1),TS(1)),(TIPROP0200
     AP(1),TP(1)),(TIR(1),TR(1)),(DELRUD(1),RUD(1))                     PROP0210
C                                                                       PROP0220
      FX = 0.0                                                          PROP0230
      FY = 0.0                                                          PROP0240
      FZ = 0.0                                                          PROP0250
      FK = 0.0                                                          PROP0260
      FM = 0.0                                                          PROP0270
      FN = 0.0                                                          PROP0280
      TL=TIME                                                           PROP0290
      IF(NPR.EQ.0.0) GO TO 5                                            PROP0300
      RUDANG=FG1(TL,NPR,TR,RUD,IR)                                      PROP0310
      RUDANG=RUDANG/RAD                                                 PROP0320
C                                                                       PROP0330
C     CALCULATE THRUSTS AND MOMENTS INDIVIDUALLY                        PROP0340
C                                                                       PROP0350
      GO TO 6                                                           PROP0360
    5 RUDANG=DELRUD(1)                                                  PROP0370
      RUDANG=RUDANG/RAD                                                 PROP0380
    6 CD=COS(RUDANG)                                                    PROP0390
      SD=SIN(RUDANG)                                                    PROP0400
      IF(NPS.EQ.0.0) GO TO 2                                            PROP0410
      THSS=FG1(TL,NPS,TS,THS,IS)                                        PROP0420
      GO TO 4                                                           PROP0430
    2 THSS=THSTS(1)                                                     PROP0440
    4 IF(NPP.EQ.0.0) GO TO 3                                            PROP0450
      THSP=FG1(TL,NPP,TP,THP,IP)                                        PROP0460
      GO TO 1                                                           PROP0470
    3 THSP=THSTP(1)                                                     PROP0480
    1 STHSTS=STHS*THSS                                                  PROP0490
      STHSTP=STHP*THSP                                                  PROP0500
      FXS=THSS*CD+STHSTS*SD                                             PROP0510
      FXP=THSP*CD-STHSTP*SD                                             PROP0520
      FYS=-STHSTS*CD+THSS*SD                                            PROP0530
      FYP=STHSTP*CD+SD*THSP                                             PROP0540
      FZS=-THSS*THETA*CD-STHSTS*CD*PHI                                  PROP0550
      FZP=-THSP*THETA*CD+STHSTP*CD*PHI                                  PROP0560
      FX=FXP+FXS                                                        PROP0570
      FY=FYP+FYS                                                        PROP0580
      FZ=FZP+FZS                                                        PROP0590
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      FKP=-FZP*YP-FYP*ZP                                                PROP0600
      FKS=FZS*YP-FYS*ZP                                                 PROP0610
      FK=FKS+FKP                                                        PROP0620
      FMS=FZS*(-XP)+FXS*ZP                                              PROP0630
      FMP=FZP*(-XP)+FXP*ZP                                              PROP0640
      FM=FMS+FMP                                                        PROP0650
      FNS=-FXS*YP-FYS*(-XP)                                             PROP0660
      FNP=FXP*YP-FYP*(-XP)                                              PROP0670
      FN=FNS+FNP                                                        PROP0680
      IF (IPROP.NE.ON) RETURN                                           PROP0690
                  WRITE(6,123)                                          PROP0700
     1FX,FY,FZ,FK,FM,FN                                                 PROP0710
  123 FORMAT(/10X,22HPROP FX,FY,FZ,FK,FM,FN  /6E15.4)                   PROP0720
      RETURN                                                            PROP0730
      END                                                               PROP0740

      SUBROUTINE RHS(VALUE)                                             RHS 0020
C                                                                       RHS 0030
      INTEGER ON                                                        RHS 0040
      COMMON /AIR/ PINF,RHOINF,GAM,IQUIT                                RHS 0050
      COMMON /BMCO / IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IYRHS 0060
      COMMON /COLUMN/ IVERT,ILATRL                                      RHS 0070
      COMMON /CONST/ PI,RAD,UO                                          RHS 0080
      COMMON /CNTRL/CONTW,CONTQ,CONTTH,QMULT,LCUVER,ACCNTZ,ACCNTW,ZEQUILRHS 0090
     1 ,THEQL,ACBASE                                                    RHS 0100
      COMMON/ENGINE/NPS,NPP,THSTS(25),THSTP(25),XF,YP,ZP,STHS,STHP,     RHS 0110
     ATIP(25),TIS(25)                                                   RHS 0120
      COMMON /FANMAP/QIN,QBFAN(25),QMFAN(25),QSFAN(25),ENBFAN,ENMFAN,   RHS 0130
     1 ENSFAN,BRPM,MRPM,SRPM,NPTSB,NPTSM,NPTSS                          RHS 0140
     2 ,PBFAN(25),PMFAN(25),PSFAN(25),TMEB(25),DELB(25),NB,TMES(25),    RHS 0150
     3DETS(25),NS                                                       RHS 0160
      COMMON /FAERO/ FXAED,FYAED,FZAED,FKAED,FMAED,FNAED                RHS 0170
      COMMON /FORBS/FXBS,FYBS,FZBS,FKBS,FMBS,FNBS,QLBS                  RHS 0180
      COMMON /FORSS/FXSS,FYSS,FZSS,FKSS,FMSS,FNSS,QLSS,FMS              RHS 0190
      COMMON /FPROP/ FXP,FYP,FZP,FKP,FMP,FNP                            RHS 0200
      COMMON / FROUDE / FN,FNCRIT                                       RHS 0210
      COMMON /FRUD/ FXRUD,FYRUD,FZRUD,FKRUD,FMRUD,FNRUD                 RHS 0220
      COMMON/GBOW/ XBOW                                                 RHS 0230
      COMMON /GEOM/     WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VCLNOM    RHS 0240
     1,DELS(4,10),XCP,ZCP                                               RHS 0250
      COMMON /GEOMBS/DETABX(11),DETABT(11),ARM1B(10),ARM2B(10)          RHS 0260
     1 ,DFBS(10),TSKIB(10)                                              RHS 0270
      COMMON /GEOMSS/DETADX(11),DETADT(11),ARM1S(10),DFSS(10),TSKIS(10) RHS 0280
     1 ,ARM2S(10)                                                       RHS 0290
      COMMON /KSWTCH/ ITHRST                                            RHS 0300
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHC,NMASS,  RHS 0310
     -                AMI(201),XI(201),YI(201),ZI(201),XS,ZS,HRHC       RHS 0320
      COMMON /MATRIX/ A(6,6)                                            RHS 0330
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      COMMON /MSIDW/ DF(2,10),DSWAV(2,10),FXH(2),FYH(2),FZH(2),FMH(2),   RHS 0340
     1               FNH(2),VFY(2),VFZ(2),FXV                            RHS 0350
      COMMON /MWAVE/ FXW(2),FYW(2),FZW(2),FKW(2),FMW(2),FNW(2)           RHS 0360
      COMMON /OPTION/I3COF,ISRGE,ITRIM,IDIA,IPITCH                       RHS 0370
      COMMON /PLENUM/XLBW,XBBW,ABW,BUBHGT                                RHS 0380
      COMMON /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT                      RHS 0390
      COMMON /PRTINT/ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,   RHS 0400
     -IRUD,IPROP,IAEROD,IRHS                                             RHS 0410
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7   RHS 0420
      COMMON /PWAVE/ FNCON,PWVCON                                        RHS 0430
      COMMON/RUDDR/ NPR,DELRUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR,   RHS 0440
     ARCLB,RTC,RUDANG,TIR(25)                                            RHS 0450
      COMMON /SIDE/FXSW,FYSW,FZSW,FKSW,FMSW,FNSW,ALSW,YSW,XLSW,CFSW,CDSWRHS 0460
     1,VAREA  ,VCHORD,VSPAN,VANGLE,VCOS,VX,VY,VZ  ,AVBMSW,DELX,VTC       RHS 0470
      COMMON/SLOPE/WATSLP,XPWV,XLXPWV,PWVHT,XPWVXS                       RHS 0480
      COMMON/SOFTBS/XBF,PBS,SINBS,COSBS,XBS,ZBS,DELYBS,DPBS,ELMAXB,YAVG RHS 0490
     1B(10),CENCAB                                                       RHS 0500
      COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,DELYSS,DPSS            RHS 0510
     1 ,ELMAXS,YAVGS(10)                                                 RHS 0520
      COMMON / VALOLD / YOLD(20)                                         RHS 0530
      COMMON /VARBLE/ VAL(40)                                            RHS 0540
      COMMON /WAVE/ ETA(4,11),AW(10),OMEGA(10),DVCLW,NWAVE,BETA,         RHS 0550
     1              FXWAV,FYWAV,FZWAV,FKWAV,FMWAV,FNWAV                  RHS 0560
     2              ,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBBAR           RHS 0570
      EQUIVALENCE (VAL(1),TIME),(VAL(2),U),(VAL(3),V),(VAL(4),W),        RHS 0580
     1(VAL(5),P),(VAL(6),Q),(VAL(7),R),(VAL(8),PHI),(VAL(9),THETA),      RHS 0590
     2(VAL(10),Z),(VAL(11),BMASS),(VAL(21),X),(VAL(22),Y),(VAL(23),PSI),RHS 0600
     3(VAL(24),PB)                                                       RHS 0610
      EQUIVALENCE (VAL(18),FANPWR)                                       RHS 0620
      EQUIVALENCE (VAL(35),PBARB),(VAL(36),PBARS)
      DATA NOTIN /0/                                                     RHS 0630
      DIMENSION ACCEL(3),ANGACL(3)                                       RHS 0640
      DIMENSION GF(6),VALUE(20)                                          RHS 0650
C     WRITE (6,9876) (VAL(J),J=1,11)
C9876 FORMAT ('0',11E12.5)
C                                                                        RHS 0660
      DO 5 J=1,20                                                        RHS 0670
    5 VALUE(J)=0.0                                                       RHS 0680
C                                                                        RHS 0690
C     CALCULATION OF BUBBLE WAVE MAKING DRAG                             RHS 0700
C                                                                        RHS 0710
      AB=ABW-(ABW-(XL*WIDTH))*(ZS+Z)/BUBHGT                              RHS 0720
      IF (IDIA.EQ.1) GO TO 6                                             RHS 0730
      FN=U/FNCON                                                         RHS 0740
      CF=.37/(FN**1.5655981)                                             RHS 0750
      FXPWAV=-PWVCON*PBBAR*CF                                            RHS 0760
      WATSLP=-FXPWAV/WEIGHT                                              RHS 0770
      VOL=VOLNOM-.5*(AB+ABW)*(Z+ZS)-DVOLW                                RHS 0780
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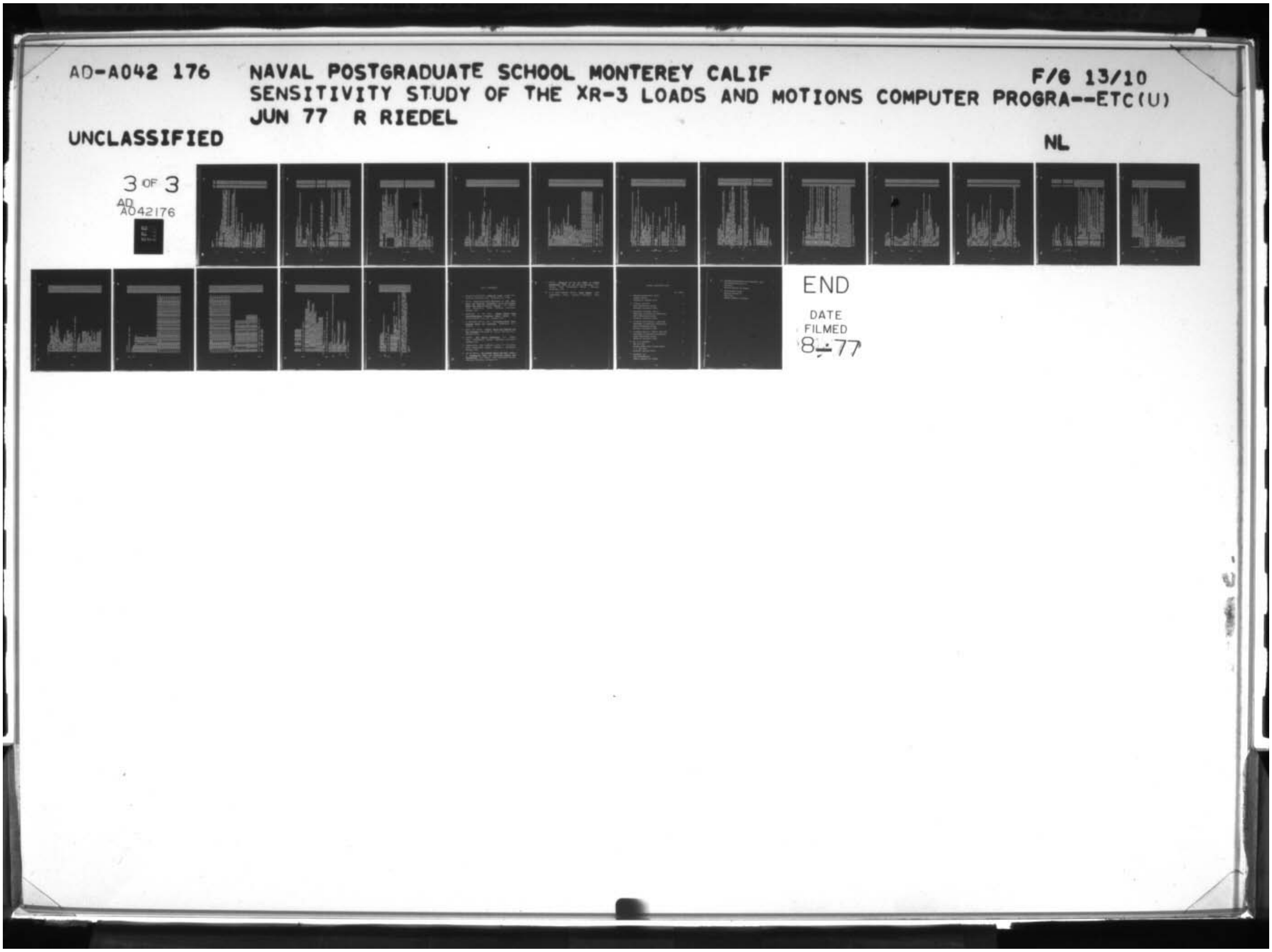
     1+.5*WATSLP*XL*AB                                                  RHS 0790
      GO TO 7                                                           RHS 0800
C                                                                       RHS 0810
C    MEMBRANE STUDY                                                     RHS 0820
C                                                                       RHS 0830
 6    PBAR=VAL(24)-PINF                                                 RHS 0840
      VOL=VOLNOM-.5*(AB+ABW)*(Z+ZS)-DVCLW+PBAR*.3175333                 RHS 0850
 7    CONTINUE                                                          RHS 0860
      PB=PINF*(BMASS/(VOL*RHOINF))**GAM                                 RHS 0870
      PBS=PB+DPBS                                                       RHS 0880
      PSS=PB+DPSS                                                       RHS 0890
      PBAR=PB-PINF                                                      RHS 0900
      ABPB=PBAR*AB                                                      RHS 0910
                                                                        RHS 0920
C     CALCULATION OF BUBBLE WAVE MAKING DRAG                            RHS 0930
C                                                                       RHS 0940
      FLCW=SQRT(2.*ABS(PBAR)/RHOINF)*SIGN(1.,PBAR)                      RHS 0950
      QLSW=CFSW*ALSW*FLCW                                               RHS 0960
C                                                                       RHS 0970
      CALL BOWSL                                                        RHS 0980
      CALL STNSL                                                        RHS 0990
C                                                                       RHS 1000
      GF(1)=FXBS+FXSS+FXSW+FXRUD+FXP+FXWAV+FXAED           +FXPWAV      RHS 1010
      IF (ITHRST.NE.ITRIM) GO TO 11                                     RHS 1020
      THSTS(1)=THSTS(1)-GF(1)/2.                                        RHS 1030
      THSTP(1)=THSTP(1)-GF(1)/2.                                        RHS 1040
      THST=THSTS(1)+THSTP(1)                                            RHS 1050
      GF(1) = 0.0                                                       RHS 1060
   11 CONTINUE                                                          RHS 1070
      GF(2)=-R*U*AM+FYBS+FYSS+FYSW+FYRUD+FYP+FYWAV+FYAED                RHS 1080
      GF(3)=WEIGHT-ABPB         +FZBS+FZSS+FZSW+FZRUD+FZP+FZWAV+FZAED   RHS 1090
      GF(4)=FKBS+FKSS+FKSW+FKRUD+FKP+FKWAV+FKAED  +ABPB*PHI*(-Z)        RHS 1100
C                                                                       RHS 1110
C     CALCULATION OF EFFECTIVE CENTER OF PRESSURE                       RHS 1120
C                                                                       RHS 1130
      XCPU=XCP+0.001975*(U/1.6889-30.0)**2-0.974                        RHS 1140
      XCPC=SHXYAX(XCPU,ZCP,THETA,PI)                                    RHS 1150
      FMBUB=ABPB*XCPC                                                   RHS 1160
      GF(5)=FMBS+FMSS+FMSW+FMRUD+FMP+FMWAV+FMAED+FMBUB+FXPWAV*ZS        RHS 1170
      FWAVZ=FXPWAV*ZS                                                   RHS 1180
      GF(6)=FNBS+FNSS+FNSW+FNRUD+FNP+FNWAV+FNAED                        RHS 1190
      IF(I3DOF.NE.1.OR.I3DOF.NE.2.OR.I3DOF.NE.3) GO TO 100
      IF(I3DOF.NE.3) GF(3)=0.0
      GF(5)=0.0                                                         RHS 1220
  100 CONTINUE                                                          RHS 1230
      DO 1 I=1,6                                                        RHS 1240
      VALUE(I)=0.0                                                      RHS 1250
      DO 1 J=1,6                                                        RHS 1260
```

```
      VALUE(I)=VALUE(I)+A(I,J)*GF(J)
    1 CCNTINUE
      IF(IPITCH.EC.1) VALUE(4)=0.0
      VALUE(7)=P
      VALUE(8)=Q
      IF(IPITCH.EQ.1) VALUE(8)=0.0
      VALUE(9)=W
      IF (I3DOF .EQ. 1 ) GO TO 325
C
C     BUBBLE PRESSURE EQUATION
C
      CCLT=QLBS+QLSS+QLSW
C
      CALL FAN
C
      CCNTRL=0.0
      VALUE(10)=RHOINF*(QIN-QOUT-CCNTRL)
      GC TO 236
  325 CCNTINUE
      VALUE(10)=0.0
  236 CCNTINUE
C
C     WRITE DATA FILE FOR MOMENT AND SHEAR CALCS., IF REQUIRED
C
      IF ( IMT.NE.1 )   GO TO 111
      NES = NSTA(3)-1
      NSS = NSTA(4)-1
      NSSL = NSS/2+1
                      WRITE (IBMFIL)   (VAL(I),I=1,24),ZBAR,PHIBAR,THEBAR,
     -                FXW,FYW,FZW,FKW,FMW,FNW,  (VALUE(I),I=1,10),
     -                DF,DSWAV,FXH,FYH,FZH,FMH,FNH,VFY,VFZ,FXV  ,
     -                FXRUD,FYRUD,FXP,FYP,FZP,   FZSS,FKSS,FMSS,FXBS,FZBS,
     -                FXAED,FYAED,FZAED,FMAED,FNAEC,FXPWAV,FXSS,FKBS,FMBS
     X ,FNBS,FNSS ,(TSKIS(I),DFSS(I),I=NSSL,NSS)
     Y             ,(TSKIB(I),DFBS(I),ARM1B(I),ARM2B(I),I=1,NBS)
  111 CCNTINUE
C
C     CCNSTANT LONGITUDINAL VELOCITY ( U )
C
      IF (ISRGE .EQ.1) VALUE(1)=0.0
C     WRITE (6,9875) (VALUE(IQX),IQX=1,10)
C9875 FCRMAT (13X,10E12.5)
      IF (ON.NE.1) RETURN
      DC 2 I=1,3
      ACCEL(I)=VALUE(I)/G
      ANGACL(I)=VALUE(I+3)*RAD
    2 CCNTINUE
      BCWACC=ACCEL(3)-XBOW*VALUE(5)/G
```

```
      STNACC=ACCEL(3)+XS*VALUE(5)/G                                    RHS 1710
      IF(IVERT.NE.ON) GC TO 10                                         RHS 1720
      ZC=Z+ZS                                                          RHS 1730
      VCLP=VCL                                                         RHS 1740
      THETAR=THETA*RAD                                                 RHS 1750
      QDEG=Q*RAD                                                       RHS 1760
   10 IF(ILATRL.NE.ON) GO TO 15                                        RHS 1770
      DEPSI=PSI*RAD                                                    RHS 1780
      PDEG=P*RAD                                                       RHS 1790
      RDEG=R*RAD                                                       RHS 1800
      BETAS=-V/U*RAD                                                   RHS 1810
      ACCLAT=(VALUE(2)+U*R)/G                                          RHS 1820
      DPHI=PHI*RAD                                                     RHS 1830
      DRFT=12.0*ZC                                                     RHS 1840
      VEL=U/1.6889                                                     RHS 1850
      DELRS=RUDANG*RAD                                                 RHS 1860
      IF(R.EQ.0.0) GO TO 115                                           RHS 1870
      TRACUS=U/R                                                       RHS 1880
      GC TO 20                                                         RHS 1890
  115 TRACUS=1.E8                                                      RHS 1900
 20   WRITE(1)TIME,BMASS,DRFT,THETAR,PBAR,BOWACC,ACCEL(3),FANPWR,PBARB,PRHS 1910
     1EARS,VAL(16),VEL,PDEG,VOLP,X,Y,QIN,QOUT,GF(1),FXPWAV,THSTS(1),THSTRHS 1920
     2P(1),QDEG,FZSS,FXSS,DPHI                                         RHS 1930
 15   IF (IRHS .NE. ON) RETURN                                         RHS 1940
      WRITE(6,77) FMBS,FMSS,FMSW,FMRUD,FMP,FMWAV,FMAED,FMBUB,FWAVZ     RHS 1950
      WRITE(6,401)FXPWAV                                               RHS 1960
      WRITE(6,200) PBAR,FANPWR,QIN,QLBS,QLSW,QLSS                      RHS 1970
      WRITE(6,215) AB,VOL                                              RHS 1980
                    WRITE(6,213) VALUE,VAL                             RHS 1990
      WRITE(6,150) GF,ACCEL,ANGACL                                     RHS 2000
      WRITE(6,175)BOWACC,STNACC                                        RHS 2010
C                                                                      RHS 2020
   77 FCRMAT('0',6X,5HFMBS=,E16.6,2X,5HFMSS=,E16.6,2X,5HFMSW=,         RHS 2030
     AE16.6,/,'0',6X,6HFMRUD=,E16.6,2X,4HFMP=,E16.6,2X,6HFMWAV=,E16.6, RHS 2040
     B/,'0',6X,6HFMAED=,E16.6,2X,6HFMBUB=,E16.6,2X,6HFWAVZ=,E16.6)     RHS 2050
  401 FCRMAT('0',6X,7HFXPWAV=,E16.6)                                   RHS 2060
  200 FCRMAT(//10X,3HRHS                                               RHS 2070
     120H GAGE PRESS. (PSF) = F7.2,5X,21HFAN POWER REQD (HP) =  F8.2,  RHS 2080
     25X,27HFAN FLOW RATE (CU FT/SEC) =  F9.2,                         RHS 2090
     3//31H LEAKAGE FLOW RATES (CU FT/SEC)  //11H BOW SEAL = F9.2,     RHS 2100
     411H SIDEWALL = F9.2,13H STERN SEAL = F9.2)                       RHS 2110
  215 FCRMAT(/13H PLENUM AREA= F9.2,10X,14HPLENUM VCLUME= F10.2)       RHS 2120
  213 FCRMAT(//12H VALUE ARRAY 2(/10E13.4)/10H VAL ARRAY 4(/10E13.4))  RHS 2130
  150 FORMAT(/10X,24HTOTAL FORCES AND MCMENTS 6E12.4/10X,24HACCELERATIONRHS 2140
     -S G,DEG/SEC2 6E12.4)                                             RHS 2150
  175 FCRMAT(/10X,16HBOW ACCEL. (G) = E12.4,21H   STERN ACCEL. (G) = E12RHS 2160
     -.4)                                                              RHS 2170
C                                                                      RHS 2180
```


AD-A042 176
NAVAL POSTGRADUATE SCHOOL MONTEREY CALIF
F/G 13/10
SENSITIVITY STUDY OF THE XR-3 LOADS AND MOTIONS COMPUTER PROGRA--ETC(U)
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      RETURN                                                            RHS 2190
      END                                                               RHS 2200
C                                                                       RUD 0010
      SUBROUTINE RUDDER                                                 RUD 0020
C                                                                       RUD 0030
      INTEGER ON                                                        RUD 0040
      COMMON /CONST/ PI,RAD,UO                                          RUD 0050
      COMMON /FRUD/ FX,FY,FZ,FK,FM,FN                                   RUD 0060
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,  RUD 0070
     -                AMI(201),XI(201),YI(201),ZI(201),XS,ZS,HRHC       RUD 0080
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7  RUD 0090
      COMMON /PRTINT/ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,  RUD 0100
     -IRUD,IPROP,IAEROD,IRHS                                            RUD 0110
      COMMON/RUDDR/ NPR,DELRUD(25),XR,YR,ZR,IRDS,TL,RSPAN,RAREA,RASPR,  RUD 0120
     ARCLB,RTC,RUDANG,TIR(25)                                           RUD 0130
      COMMON /VARBLE/ VAL(40)                                           RUD 0140
      EQUIVALENCE (VAL(1),TIME),(VAL(2),U),(VAL(3),V),(VAL(4),W),       RUD 0150
     1(VAL(5),P),(VAL(6),Q),(VAL(7),R),(VAL(8),PHI),(VAL(9),THETA),     RUD 0160
     2(VAL(10),Z),(VAL(11),BMASS),(VAL(21),X),(VAL(22),Y),(VAL(23),PSI),RUD 0170
     3(VAL(24),PB)                                                      RUD 0180
      EQUIVALENCE (DELRUD(1),RUD(1)),(TIR(1),TR(1))                     RUD 0190
      DIMENSION RUD(1),TR(1)                                            RUD 0200
      EQUIVALENCE (VAL(18),FANPWR)                                      RUD 0210
      DATA ENU /1.28E-5/                                                RUD 0220
C                                                                       RUD 0230
C     CALCULATE PROGRAMMED RUDDER DEFLECTION                            RUD 0240
C                                                                       RUD 0250
      TL=TIME                                                           RUD 0260
      IF(NPR.EQ.0.0) GO TO 5                                            RUD 0270
      GO TO 6                                                           RUD 0280
    5 RUDANG=DELRUD(1)                                                  RUD 0290
      RUDANG=RUDANG/RAD                                                 RUD 0300
      GO TO 7                                                           RUD 0310
    6 RUDANG=FG1(TL,NPR,TR,RUD,IR)                                      RUD 0320
      RUDANG=RUDANG/RAD                                                 RUD 0330
C                                                                       RUD 0340
C     SIDE FORCE ON RUDDER                                              RUD 0350
C                                                                       RUD 0360
    7 DSR=Z+ZS-XR*THETA                                                 RUD 0370
      ENDFAC=(1.+DSR/(DSR+RSPAN))                                       RUD 0380
      VH=V+XR*R-ZR*P                                                    RUD 0390
      QQ=HRHO*U*U*RAREA                                                 RUD 0400
      EFFANG=RUDANG-ENDFAC*VH/U                                         RUD 0410
      FY=2.*QQ*ENDFAC*RCLB*EFFANG                                       RUD 0420
C                                                                       RUD 0430
C     DRAG FORCE ON RUDDER                                              RUD 0440
C                                                                       RUD 0450
```

```
      REY=U*(RAREA/RSPAN)/ENU
      CFR=.427/(ALOG10(REY)-.407)**2.64
      PI8=PI/8.
      CC=2.*CFR+ PI8*RTC*RTC*(1.+G*RSPAN/(U*U))+RCLB*EFFANG*EFFANG
      FX=-2.*CD*RAREA*HRHO*U*U
      FZ=C.
      FK=-ZR*FY
      FM=FX*ZR
      FN=XR*FY
      IF(IRUD.NE.CN) RETURN
                WRITE(6,123)
     1FX,FY,FZ,FK,FM,FN
C
  123 FCRMAT(/10X,24HRUDDER FX,FY,FZ,FK,FM,FN /6E15.4)
C
      RETLRN
      ENC
C
      SLBROUTINE SAM
C
      WRITE (6,10)
   10 FCRMAT (1H1,'YOU HAVE CALLED A DUMMY SAM SUBROUTINE.'/
     110X,'CHANGE TO BHISES TO USE THE SAM SUBROUTINE.')
      RETLRN
      ENC
      SLBROUTINE SIDEWL
C
      INTEGER ON
      CCMMON /AIR/ PINF,RHOINF,GAM,IQUIT
      CCMMON /BMCO / IMM,IMNX,IMNY,IBMFIL,BTIME,INT,XMI(10),YMI(7),IX,IY
      CCMMON /CONST/ PI,RAD,UO
      CCMMCN /GEOM/     WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM
     1,CELS(4,10),XCP,ZCP
      CCMMCN /GEOMSW/ XAVG(10),DS
      CCMMON /KSWTCH/ ITHRST
      CCMMCN /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,
     -                AMI(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO
      CCMMON /MSIDW/ DF(2,10),DSWAV(2,1C),FXH(2),FYH(2),FZH(2),FMH(2),
     1               FNH(2),VFY(2),VFZ(2),FXV
      CCMMCN /PLENUM/XLBW,XBBW,ABW,BUBHGT
      CCMMCN /PRIME/ STIME,FTIME,DELT,DELPNT,TPRINT
      CCMMON /PRTINT/ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,
     -IRUD,IPROP,IAEROD,IRHS
      CCMMCN /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7
      CCMMON /SIDE/FX   ,FY   ,FZ   ,FK   ,FM   ,FN   ,ALSW,YSW,XLSW,CFSW,CDSW
     1,VAREA   ,VCHORD,VSPAN,VANGLE,VCOS,VX,VY,VZ  ,AVBMSW,DELX,VTC
```

```
      COMMON /SLOPE/WATSLP,XPWV,XLXPWV,XPWVXS                           SDWL0230
      COMMON /VARBLE/ VAL(40)                                           SDWL0240
      COMMON /WAVE/ ETA(4,11),AW(10),OMEGA(10),DVCLW,NWAVE,BETA,        SDWL0250
     1              FXWAV,FYWAV,FZWAV,FKWAV,FMWAV,FNWAV                 SDWL0260
     2             ,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,FBBAR           SDWL0270
      COMMON /WAVTAB/ NAL,DAL,SAL,NDS,DDS,SDS,NTH,DTH,STH,NBB,DBB,SBB,  SDWL0280
     1          AC1(20,5,7),AC2(20,5,7),AC3(20,5,7),AC4(20,5,7),        SDWL0290
     2          AC5(20,5,7),AC6(20,5,7),AC7(20,5,7)                     SDWL0300
     3         ,AC0(20,5,7),AC00(20,5,7),AC8(20,5,7),                   SDWL0310
     4          AS1(20,5,7),AS2(20,5,7),AS3(20,5,7),AS4(20,5,7),        SDWL0320
     5          AS5(20,5,7),AS6(20,5,7),AS7(20,5,7)                     SDWL0330
     6         ,AS0(20,5,7),AS00(20,5,7),AS8(20,5,7)                    SDWL0340
     7         ,BB(36),XREF,RX                                          SDWL0350
      EQUIVALENCE               (VAL(2),U),(VAL(3),V),(VAL(4),W),       SDWL0360
     1(VAL(5),P),(VAL(6),Q),(VAL(7),R),(VAL(8),PHI),(VAL(9),THETA),     SDWL0370
     2(VAL(10),Z),(VAL(11),BMASS),(VAL(21),X),(VAL(22),Y),(VAL(23),PSI),SDWL0380
     3(VAL(24),PB)                                                      SDWL0390
      DIMENSION GAP(2,11),DSW(2,11)                                     SDWL0400
      DIMENSION FZHOLD(2), FZHDRP(2)                                    SDWL0410
      DATA ENU /1.28E-5/                                                SDWL0420
C                                                                       SDWL0430
      PBAR=PB-PINF
      PBHEAD=PBAR/(RHO*G)                                               SDWL0440
C                                                                       SDWL0450
C     GAP OR WETTED DRAFT CALCULATION                                   SDWL0460
C                                                                       SDWL0470
      DO 10 J=1,2                                                       SDWL0480
      N=NSTA(J)                                                         SDWL0490
      DO 10 K=1,N                                                       SDWL0500
      DD=ZS+Z+YY(J,K)*PHI-XX(1,K)*THETA+ETA(J,K)                        SDWL0510
      DDIN=DD-WATSLP*(XPWVXS-XX(J,K))                                   SDWL0520
      IF(DDIN.LT.BUBHGT) GO TO 101                                      SDWL0530
      IF ( VAL(1)-TOLD .LT. DELPNT )  GO TO 101                         SDWL0540
      TOLD = VAL(1)                                                     SDWL0550
      WRITE (6,100) XX(J,K),VAL(1),DD                                   SDWL0560
  100 FORMAT(/10X,43HWATER CONTACT WITH TOP OF BUBBLE CHAMBER AT F7.2,  SDWL0570
     -14H FT.     TIME = F7.2,19H SEC.     IMMERSION= F7.2,4H FT. )     SDWL0580
  101 CONTINUE                                                          SDWL0590
      DSW(J,K)=(SIGN(1.,DD)+1.)*DD/2.                                   SDWL0600
      IF (DDIN) 6,8,8                                                   SDWL0610
    6 IF(DSW(J,K)-PBHEAD) 7,8,8                                         SDWL0620
    7 GAP(J,K)=-DDIN*(1.-(DSW(J,K))/PBHEAD)                             SDWL0630
      GO TO 10                                                          SDWL0640
    8 GAP(J,K)=0.0                                                      SDWL0650
   10 CONTINUE                                                          SDWL0660
C                                                                       SDWL0670
C     LEAKAGE AREA                                                      SDWL0680
C                                                                       SDWL0690
```

```
      ALSW=0.0
      DO 20 J=1,2                                                       SDWL0710
      N=NSTA(J)-1                                                       SDWL0720
      DO 20 I=1,N                                                       SDWL0730
      ALSW=ALSW+(GAP(J,I)+GAP(J,I+1))*DELX/2.                           SDWL0740
   20 CONTINUE                                                          SDWL0750
C                                                                       SDWL0760
C     CROSS-FLOW DRAG ON SIDEWALLS                                      SDWL0770
C                                                                       SDWL0780
      FYD=0.0                                                           SDWL0790
      FKD=0.0                                                           SDWL0800
      FND=0.0                                                           SDWL0810
      DO 15 I=1,2                                                       SDWL0820
      N=NSTA(I)-1                                                       SDWL0830
      DO 15 J=1,N                                                       SDWL0840
      DSWAV(I,J)=(DSW(I,J)+DSW(I,J+1))/2.                               SDWL0850
      VREL      =V+XAVG(J)*R-(ZS-DSWAV(I,J)/2.)*P                       SDWL0860
      DF(I,J)=-  HRHO*CDSW*VREL      *ABS(VREL      )*DELX      *DSWAV(I,J)SDWL0870
      FYD=FYD+DF(I,J)                                                   SDWL0880
      FND=FND+DF(I,J)*XAVG(J)                                           SDWL0890
   15 FKD=FKD-(ZS-DSWAV(I,J)/2.)*DF(I,J)                                SDWL0900
C                                                                       SDWL0910
C     SET UP STERN LIMIT OF FORCE DETERMINATION                         SDWL0920
C                                                                       SDWL0930
      XSS = -XS                                                         SDWL0940
      GO TO 16                                                          SDWL0950
      ENTRY SIDWLM                                                      SDWL0960
      XSS = XMI(IX)                                                     SDWL0970
   16 IP=1.+(THETA*RAD-STH)/DTH                                         SDWL0980
      IP=MAX0(MIN0(IP,NTH),1)                                           SDWL0990
      IP1=MIN0(IP+1,NTH)                                                SDWL1000
      DTHETA=(IP-1)*DTH+STH                                             SDWL1010
      CIP= (THETA*RAD-DTHETA)/DTH                                       SDWL1020
C                                                                       SDWL1030
C     CALC REYNOLDS NO. AND DRAG COEFF.                                 SDWL1040
C                                                                       SDWL1050
      REY=U*XLSW/ENU                                                    SDWL1060
      CDT=.427/(ALOG10(REY)-.407)**2.64                                 SDWL1070
C                                                                       SDWL1080
C     SIDEWALL FORCES, P/S                                              SDWL1090
C                                                                       SDWL1100
      DO 40 J=1,2                                                       SDWL1110
      WAREA=0.0                                                         SDWL1120
      N=NSTA(J)-1                                                       SDWL1130
      NI = (XSS+XS)*N/XLSW+1.5                                          SDWL1140
      DO 21 I=NI,N                                                      SDWL1150
      ZOR1=1.                                                           SDWL1160
      IF(DSWAV(J,I).EQ. 0.0) ZOR1=0.0                                   SDWL1170
```

```
21    WAREA=WAREA+DELX*(2.*DSWAV(J,I)+ZCR1*AVBMSW)
      FXH(J)=-   HRHO*CDT*WAREA*U*U
      FM1=2*J-3
      YLSW=FM1*YSW
      CS= Z    +ZS+YLSW*PHI
      DSS=DS-XSS*THETA
      ZCR1=(SIGN(1.,DSS)+1.)/2.
      CSS=DSS*ZOR1
      ICSS=1.5+(DSS-SBB)/DBB
      ICSS=MINO(NBB,IDSS)
      BS=BB(ICSS)
      ZCR1=(SIGN(1.,DSS)+1.)/2.
      CSS=DSS*ZOR1
      CRBOW=DSS-(XX(J,N+1)-XSS)*THETA
      IF(DRBOW.LT.0.0) DRBOW=0.0
      A33S=(RHO*PI*BS**2)/8.
      A22S=(RHO*.4*PI*DSS**2)/2.
      IF(THETA.LT.0.0) A22S=.4*RHO*PI*DRBOW*DRBOW/2.
      CSR=DS-(XREF-XS)*THETA
      IC=1.+(DSR*12.-SDS)/DDS
      ID=MAXO(MINO(ID,NDS),1)
      CCSR =(ID-1)*DDS +SDS
      IC1=MINO(ID+1,NDS)
      DIC= (DSR*12.-DDSR)/DDS
      BCO=ACO( 1,ID,IP)
      BCOO=ACOO( 1,ID,IP)
      BC2=AC2( 1,ID,IP)
      BC5 = AC5(1,ID,IP)
      BC6 = AC6(1,ID,IP)
      BCO =BCO +DID*(ACO (1,ID1,IP)-BCO ) +DIP*(ACO (1,ID,IP1)-BCO
     1    +DID*(ACO (1,ID1,IP1)-ACO (1,ID,IP1)-ACO (1,ID1,IP)+BCO ))
      BCOC=BCOO+DID*(ACOO(1,ID1,IP)-BCOO) +DIP*(ACOO(1,IC,IP1)-BCOO
     1    +DID*(ACOO(1,ID1,IP1)-ACOO(1,ID,IP1)-ACOC(1,ID1,IP)+BCOO))
      BC2 =BC2 +DID*(AC2 (1,ID1,IP)-BC2 ) +DIP*(AC2 (1,ID,IP1)-BC2
     1    +DID*(AC2 (1,ID1,IP1)-AC2 (1,IC,IP1)-AC2 (1,ID1,IP)+BC2 ))
      BC5 =BC5 +DID*(AC5 (1,ID1,IP)-BC5 ) +DIP*(AC5 (1,ID,IP1)-BC5
     1    +DID*(AC5 (1,ID1,IP1)-AC5 (1,ID,IP1)-AC5 (1,ID1,IP)+BC5 ))
      BC6 =BC6 +DID*(AC6 (1,ID1,IP)-BC6 ) +DIP*(AC6 (1,ID,IP1)-BC6
     1    +DIC*(AC6 (1,ID1,IP1)-AC6 (1,ID,IP1)-AC6 (1,ID1,IP)+BC6 ))
C
C     SHIFT MCMENT CENTER FRCM XREF TO C.G.
C
      BCCO = BCOO-(XS-XREF)*BCO
      BC6  = BC6 -(XS-XREF)*BC5
C
C     HYDROSTATIC AND HYDRODYNAMIC FORCES
C
      FZH(J) =-G*BCO-U*U*A33S*THETA-U*A33S*W+Q*U*(-BC2+A33S*XSS)
```

```
     1    -U*A33S*P*YLSW                                                 SDWL1660
      FMH(J) =-U*XSS*XSS*A33S*Q+G*BC00+U*(A33S*XSS+BC2)*(W+U*THETA      SDWL1670
     1  +YLSW*P)                                                         SDWL1680
      FYH(J) =-A22S*U*(V+XSS*R  -ZS*P)                                   SDWL1690
      FNH(J) = FYH(J)*XSS-U*((V-ZS*P)*BC5+R*BC6)                         SDWL1700
C                                                                        SDWL1710
C     ADD VERTICAL FORCE DUE TO DEADRISE PROJECTION OF LATERAL FORCE     SDWL1720
C                                                                        SDWL1730
      DDRANG=0.0                                                         SDW*1740
      IF (DS.GT.0.5833) DDRANG=(DS-0.5833)*0.0629                        SDW*1750
      DRANG=1.021+DDRANG-PM1*PHI                                         SDW*1760
      CTNDR= COTAN(DRANG)                                                SDW*1770
      RUDSIG=SIGN(1.,RUDANG)                                             SDW*1780
      IF (RUDSIG.NE.PM1) CTNDR=PM1*TAN(PHI)                              SDW*1781
      FZHOLD(J)=FZH(J)                                                   SDWL1790
      FZHDRP(J)=PM1*FYH(J)*CTNDR*PROMO1                                  SDWL1800
      FZH(J)=FZH(J)+FZHDRP(J)                                            SDWL1810
      IF (IMT.EQ.2)  GO TO 40                                            SDWL1820
C                                                                        SDWL1830
C     CALC OF FORCE ON VENTRAL FINS REMOVED                              SDWL1840
C                                                                        SDWL1850
   39 CONTINUE                                                           SDWL1860
   40 CONTINUE                                                           SDWL1870
      IF (IMT.EQ.2) GO TO 41                                             SDWL1880
C                                                                        SDWL1890
C     TOTAL SIDEWALL FORCES AMD MOMENTS                                  SDWL1900
C                                                                        SDWL1910
      FX=FXH(1)+FXH(2)                                                   SDWL1920
      FY=FYH(1)+FYH(2)                                                   SDWL1930
      FZ=FZH(1)+FZH(2)                                                   SDWL1940
      FK=(FZH(2)-FZH(1))*YSW           +FKD -FY*ZS                       SDWL1950
      FY=FY+FYD                                                          SDWL1960
      FM=FMH(1)+FMH(2)+ZS*FX                                             SDWL1970
      FN= FND +FNH(1)+FNH(2)  +(FXH(1)-FXH(2))*YSW                       SDWL1980
C                                                                        SDWL1990
C     DRAG FORCE ON FINS REMOVED                                         SDWL2000
C                                                                        SDWL2010
   41 CONTINUE                                                           SDWL2020
C                                                                        SDWL2030
C     ADD ROLL DAMPING DUE TO VERTICAL WAVE GENERATION                   SDWL2040
C                                                                        SDWL2050
      DSS=Z+ZS-XSS*THETA                                                 SDWL2060
      ZOR1=(SIGN(1.,DSS)+1.)/2.                                          SDWL2070
      DSS=DSS*ZOR1                                                       SDWL2080
      DS=Z+ZS                                                            SDWL2090
      DSR=DS-(XREF-XS)*THETA                                             SDWL2100
      ID=1.+(DSR*12.-SDS)/DDS                                            SDWL2110
      ID=MAX0(MIN0(ID,NDS),1)                                            SDWL2120
```

```
      DDSR=(ID-1)*DDS+SDS
      ID1=MINO(ID+1,NDS)
      DID= (DSR*12.-DDSR)/DDS
      BC2=AC2(1,ID,IP)
      BC2=BC2 +DID*(AC2 (1,ID1,IP)-BC2 ) +DIP*(AC2 (1,ID,IP1)-BC2
     1    +DID*(AC2 (1,ID1,IP1)-AC2 (1,ID,IP1)-AC2 (1,ID1,IP)+BC2 ))
      FKOLD=FK
      FK=FK-PROMO2*YSW*YSW*BC2*P/PI
      FZH(1)=FZH(1)+PROMO2/2.*YSW*BC2*P/PI
      FZH(2)=FZH(2)-PROMO2/2.*YSW*BC2*P/PI
      IF(PROMO3.EQ.1.0) WRITE(6,200) VAL(1), FZHOLD(1), FZHOLD(2),
     1FZHDRP(1), FZHDRP(2), FZH(1), FZH(2), FKOLD, FK
  200 FORMAT(/2X,'TIME=',1X,E15.4,2X,'OLD VERTICAL FORCES',2(5X,E15.4)/
     125X,'VERTICAL DEADRISE FORCES',2(5X,E15.4)/25X,'NEW VERTICAL FORCE
     2S',2(5X,E15.4)/25X,'OLD AND NEW ROLL MOMENTS',2(5X,E15.4)/)
      IF (ISIDWL.NE.ON) RETURN
      DO 42 I=1,2
      DO 42 J=1,11
      GAP(I,J)=12.0*GAP(I,J)
   42 DSW(I,J)=12.0*DSW(I,J)
      WRITE( 6,123) ((GAP(I,J),J=1,11),I=1,2),((DSW(I,J),J=1,11),I=1,2),
     1 FX,FY,FZ,FK,FM,FN
C
  123 FORMAT(/10X,8HSIDEWALL /25H GAP (FT.) (STERN TO BOW) /14H PORT SID
     1EWALL /11F10.5/14H STBD SIDEWALL /11F10.5/37H IMMERSION DEPTH (FT.
     2) (STERN TO BOW) /14H PORT SIDEWALL /11F10.5/14H STBD SIDEWALL /
     3 11F10.5/10X,26HSIDEWALL FX,FY,FZ,FK,FM,FN /6E15.4)
C
      RETURN
      END

C
      FUNCTION SHXYAX (X,Z,ANGYAX,PI)
C
      H=SQRT(X**2+Z**2)
      IF(X.EQ.0.0) GO TO 1
      ARG=Z/X
      ANGOLD=ATAN(ARG)
      IF(ANGOLD.GE.0.0) GO TO 2
      ANGNEW=ANGOLD+PI-ANGYAX
      GO TO 3
    1 ANGNEW=PI/2.0-ANGYAX
      GO TO 3
    2 ANGNEW=ANGOLD-ANGYAX
    3 SHXYAX=H*COS(ANGNEW)
C
      RETURN
      END
```

```
C
      SUBROUTINE STNSL
C
      INTEGER ON
      COMMON /AIR/ PINF,RHOINF,GAM,IQUIT
      COMMON /CONST/ PI,RAD,U0
      COMMON /FORSS/ FX,FY,FZ,FK,FM,FN,QL,FMS
      COMMON /GEOM/ WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VOLNOM,DELS(4,
     110),XCP,ZCP
      COMMON /GEOMSS/ DETADX(11),DETADT(11),ARM1S(10),DFSS(10),TSKIS(10)
     1,ARM2S(10)
      COMMON /KSWTCH/ ITHRST
      COMMON /LEAKER/ ALEAK,CFSS
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,AM
     1I(201),XI(201),YI(201),ZI(201),XS,ZS,HRHO
      COMMON /PRTINT/ ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBOWSL,ISTNSL,IWAVES,I
     1RUD,IPROP,IAEROD,IRHS
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7
      COMMON/SLOPE/WATSLP,XPWV,XLXPWV,PWVHT,XPWVXS
      COMMON /SOFTSS/ XLF,PSS,SINTH,COSTH,XSS,ZSS,DELYSS,DPSS,ELMAXS,YAV
     1GS(10)
      COMMON /STSLR/ CPHI,CPHID
      COMMON /VALOLD/ YOLD(20)
      COMMON /VARBLE/ VAL(40)
      COMMON /WAVE/ ETA(4,11),AW(10),OMEGA(10),OVCLW,NWAVE,BETA,FXWAV,FY
     1WAV,FZWAV,FKWAV,FMWAV,FNWAV,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PB
     2BAR
      EQUIVALENCE (VAL(1),TIME), (VAL(2),U), (VAL(3),V), (VAL(4),W), (VA
     1L(5),P), (VAL(6),Q), (VAL(7),R), (VAL(8),PHI), (VAL(9),THETA), (VA
     2L(10),Z), (VAL(11),BMASS), (VAL(21),X), (VAL(22),Y), (VAL(23),PSI)
     3, (VAL(24),PB)
      DIMENSION GAP(11), ELSKI(11), ELSKIL(11), AIRLEN(11), CTNSL(6,24)
      DATA ENU,UWSKI,CLSKI,GPS,HINGHT/1.28E-5,0.0,1.5708,.4644,1.875/
      DATA CTNSL/0.0,3.8,7.0,9.9,12.3,15.0,0.0,4.1,7.3,10.5,13.2,15.7,0.
     10,4.3,7.7,11.0,13.7,16.7,0.0,4.7,8.2,11.5,14.5,17.4,0.0,5.2,8.9,12
     2.4,15.4,18.3,0.0,5.5,9.4,13.1,16.1,19.2,0.0,5.8,9.9,13.8,17.1,20.6
     3,0.0,6.1,10.6,14.7,18.4,21.9,0.0,6.4,11.0,15.3,19.3,23.3,0.0,6.6,1
     41.7,16.4,20.5,24.5,0.0,6.9,12.3,17.6,22.1,25.7,0.0,7.2,13.5,19.6,2
     54.1,28.3,0.0,8.2,15.3,22.1,26.3,30.8,0.0,9.6,17.5,24.2,29.7,34.6,0
     6.0,11.9,20.0,25.4,32.3,38.0,0.0,14.0,23.3,30.0,35.8,41.0,0.0,17.5,
     725.5,32.5,39.7,44.5,0.0,21.6,30.0,38.7,42.0,47.0,0.0,24.6,33.7,41.
     80,45.0,48.7,0.0,28.3,38.5,45.0,48.7,48.7,0.0,35.0,45.0,48.7,48.7,4
     98.7,0.0,40.0,48.7,48.7,48.7,48.7,0.0,48.7,48.7,48.7,48.7,48.7,0.0,
     $48.7,48.7,48.7,48.7,48.7/
C
      IF (ELMAXS.GT.HINGHT) ELMAXS=HINGHT
      DO 1 J=1,11
```

```
      GAP(J) = 0.0
      ELSKI(J) = 0.0
      ELSKIL(J) = 0.0
      AIRLEN(J) = 0.0
    1 CCNTINUE
C
C     'EFDEP' IS THE EFFECTIVE LIFTING DEPTH OF T[illegible]ERN SEAL
C
      EFCEP = 6.0
      MM = EFCEP
      ALSS = C.0
      FX = 0.0
      FZ = 0.0
      FK = 0.C
      FM = 0.C
      FN = 0.0
      AGAP1 = 0.0
      AGAP2 = 0.0
      AGAPA1 = 0.0
      DELP = PSS-PB
      IF (DELP.LT.0.0) DELP=0.0
      PEAR = PB-PINF
C
C     CALCULATE ELSKI HERE.
C
      SINCIF = SINTH-COSTH*THETA
      CCSDIF = COSTH+SINTH*THETA
      X1 = XSS+ZSS*THETA-XLF*SINDIF
      Z1 = (-Z-ZSS+XSS*THETA-ELMAXS*CCS(THETA))
C
C     CALCULATE GAP HERE.
C
      N = NSTA(4)
      DC 2 K=1,N
      ELSKI(K) = (ETA(4,K)-DETADX(K)*(XX(4,K)-X1)-Z1)+YY(4,K)*PHI
     1-XPWV*WATSLP
      IF (ELSKI(K).GT.HINGHT) ELSKI(K)=HINGHT
      ELSKIL(K) = ELSKI(K)+GPS
      IF (ELSKIL(K).GT.HINGHT) ELSKIL(K)=HINGHT
      IF (ELSKIL(K).LT.(HINGHT-ELMAXS)) ELSKIL(K)=HINGHT-ELMAXS
      GAP(K) = -ELSKI(K)+(HINGHT-ELMAXS)
      IF (GAP(K).LT.0.0) GAP(K)=0.0
      MM1 = ELSKIL(K)*12.0
      MM2 = MM1+1
      MM3 = MM2+1
      DLINC = ELSKIL(K)*12.0-MM1
      STNSL1 = CTNSL(MM,MM2)
      STNSL2 = CTNSL(MM,MM3)
```

```
      AIRLEN(K) = ((STNSL2-STNSL1)*DLINC+STNSL1)/12.0
    2 CONTINUE
      N = NSTA(4)-1
      DO 5 J=1,N
      ELSKIA = (ELSKI(J+1)+ELSKI(J))/2.
      ELSKLA = (ELSKIL(J+1)+ELSKIL(J))/2.0
      AIRLAV = (AIRLEN(J+1)+AIRLEN(J))/2.0
      AGAP = ELSKLA-ELSKIA
      AGAP1 = AGAP
      IF (AGAP.LT.GPS) AGAP=GPS
      IF (AGAP1.GT.GPS) AGAP1=GPS
      ARM1S(J) = XX(4,J)+ELSKIA/2.
      ARM2S(J) = ZS-ELSKIA
      DFSS(J) = -DELP*DELYSS*AIRLAV/(GPS/AGAP)**2.0
      IF (AIRLAV.LE.0.0) GO TO 3
      ARG = .5*RHO*U*U*AIRLAV*DELYSS
      RESKI = U*AIRLAV/ENU
      CDTSKI = .427/(ALOG10(RESKI)-.407)**2.64
      TSKIS(J) = -ARG*CDTSKI
C
C     THE FOLLOWING CARD REMOVES WATER DRAG EFFECTS OF STERN SEAL
C
      TSKIS(J) = 0.0
      GO TO 4
    3 TSKIS(J) = 0.0
    4 CONTINUE
      FX = FX+TSKIS(J)
      FZ = FZ+DFSS(J)
      FK = FK+DFSS(J)*YAVGS(J)
      FM = FM-DFSS(J)*ARM1S(J)+TSKIS(J)*ARM2S(J)
      FN = FN-TSKIS(J)*YAVGS(J)
      ALSS = ALSS+(GAP(J)+GAP(J+1))*DELYSS/2.0
      AGAP2 = AGAP2+AGAP1
      AGAPA1 = AGAP2/J
    5 CONTINUE
      ALSS = ALSS+ALEAK*(AGAPA1/GPS)
      SQFAC = SQRT(2.*ABS(PBAR)/RHOINF)
      CL = CFSS*ALSS*SQFAC*SIGN(1.,PBAR)
      IF (ISTNSL.NE.ON) RETURN
      WRITE (6,6) GAP,AIRLEN,FX,FY,FZ,FK,FM,FN
C
    6 FORMAT (//12H  STERN SEAL/26H  GAP (FT.) PORT TO STBD. /11E11.3/28
     1H  AIRLEN(FT.) PORT TO STBD. /11E11.3/10X,23HSTNSL FX,FY,FZ,FK,FM,
     2FN/6E15.4)
C
      RETURN
      END
```

```
C
      FUNCTION T1(X)
C
      IF(ABS(X)-.1) 10,10,20
   10 T1=X*(1.-X*X/10.0)/3.
      RETURN
   20 T1=(SIN(X)-X*COS(X))/(X*X)
      RETURN
      END
C
      FUNCTION T2(X)
C
      IF(ABS(X)-.1) 10,10,20
10    T2=1.-X*X/6.
      RETURN
20    T2=SIN(X)/X
      RETURN
      END
C
      SUBROUTINE WAVES(TIME)
C
      INTEGER ON
      COMMON /BMCO / IMM,IMNX,IMNY,IBMFIL,BTIME,IMT,XMI(10),YMI(7),IX,IY
      COMMON /CONST/ PI,RAD,UO
      COMMON /GEOM/     WIDTH,XL,XX(4,11),YY(4,11),NSTA(4),AB,VCLNOM
     1,CELS(4,10),XCP,ZCP
      COMMON /GEOMBS/DETABX(11),DETABT(11),ARM1B(10),ARM2B(10)
     1 ,CFBS(10),TSKIB(10)
      COMMON /GEOMSS/DETACX(11),DETADT(11),ARM1S(10),DFSS(10),TSKIS(10)
     1 ,ARM2S(10)
      COMMON /MASSES/ AM,AIXX,AIYY,AIZZ,AIXZ,AIMAX,G,WEIGHT,RHO,NMASS,
     -                AMI(201),XI(201),YI(201),ZI(201),XS,ZS,HRHC
      COMMON /MWAVE/ FXW(2),FYW(2),FZW(2),FKW(2),FMW(2),FNW(2)
      COMMON /PLENUM/XLBW,XBBW,ABW,BUBHGT
      COMMON /PRTINT/ON,IACCEL,IVEL,ITRAJ,ISIDWL,IBCWSL,ISTNSL,IWAVES,
     -IRUD,IPROP,IAEROD,IRHS
      COMMON /PROMOD/ PROMO1,PROMO2,PROMO3,PROMO4,PROMO5,PROMO6,PROMO7
      COMMON /RISER/ AMPTC
      COMMON /SIDE/FXSW,FYSW,FZSW,FKSW,FMSW,FNSW,ALSW,YSW,XLSW,CFSW,CDSW
     1,VAREA   ,VCHORD,VSPAN,VANGLE,VCOS,VX,VY,VZ  ,AVBMSW,DELX,VTC
      COMMON /VARBLE/ VAL(40)
      COMMON /WAVE/ ETA(4,11),AW(10),OMEGA(10),DVCLW,NWAVE,BETA,
     1              FXWAV,FYWAV,FZWAV,FKWAV,FMWAV,FNWAV
     2              ,ZBAR,PHIBAR,THEBAR,TC,COSBET,SINBET,PBBAR
      COMMON /WAVTAB/ NAL,DAL,SAL,NDS,DCS,SDS,NTH,DTH,STH,NBB,DBB,SBB,
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     1           AC1(20,5,7),AC2(20,5,7),AC3(20,5,7),AC4(20,5,7),           WAVS0280
     2           AC5(20,5,7),AC6(20,5,7),AC7(20,5,7)                        WAVS0290
     3           ,AC0(20,5,7),AC00(20,5,7),AC8(20,5,7),                     WAVS0300
     4           AS1(20,5,7),AS2(20,5,7),AS3(20,5,7),AS4(20,5,7),           WAVS0310
     5           AS5(20,5,7),AS6(20,5,7),AS7(20,5,7)                        WAVS0320
     6           ,AS0(20,5,7),AS00(20,5,7),AS8(20,5,7)                      WAVS0330
     7           ,BB(36),XREF,RX                                            WAVS0340
      DIMENSICN WC0(2),WC00(2),WC1(2),WC2(2),WC3(2),WC4(2),WC5(2),WC6(2)WAVS0350
     1          ,WC7(2),WC8(2)                                              WAVS0360
      DIMENSION WS0(2),WS00(2),WS1(2),WS2(2),WS3(2),WS4(2),WS5(2),WS6(2)WAVS0370
     1          ,WS7(2),WS8(2)                                              WAVS0380
      ECUIVALENCE                  (VAL(2),U),(VAL(3),V),(VAL(4),W),        WAVS0390
     1(VAL(5),P),(VAL(6),Q),(VAL(7),R),(VAL(8),PHI),(VAL(9),THETA),         WAVS0400
     2(VAL(10),Z),(VAL(11),BMASS),(VAL(21),X),(VAL(22),Y),(VAL(23),PSI),WAVS0410
     3(VAL(24),PB)                                                          WAVS0420
      ECUIVALENCE (VAL(16),ETACG)                                           WAVS0430
C                                                                           WAVS0440
      IF (NWAVE.EC.0) RETURN                                                WAVS0450
C                                                                           WAVS0460
C     CALCULATION OF SHIFT OF XCPO                                          WAVS0470
C                                                                           WAVS0480
      XCPL=XCP+0.001975*(U*0.5921-30.0)**2-0.974                            WAVS0490
      XCPC=SHXYAX(XCPU,ZCP,THETA,PI)                                        WAVS0500
      GAMMA=BETA-PSI                                                        WAVS0510
      SIGAM=SIN(GAMMA)                                                      WAVS0520
      CCGAM=CCS(GAMMA)                                                      WAVS0530
      FC= -X*COSBET -Y*SINBET                                               WAVS0540
      DVCLW=0.0                                                             WAVS0550
      ETACG=0.0                                                             WAVS0560
      N=NSTA(3)                                                             WAVS0570
      DC 1 J=1,N                                                            WAVS0580
      DETABX(J)=0.0                                                         WAVS0590
    1 CCNTINUE                                                              WAVS0600
      N=NSTA(4)                                                             WAVS0610
      DC 2 J=1,N                                                            WAVS0620
      DETADX(J)=0.0                                                         WAVS0630
    2 CCNTINUE                                                              WAVS0640
      DC 10 J=1,4                                                           WAVS0650
      N=NSTA(J)                                                             WAVS0660
      DC 10 K=1,N                                                           WAVS0670
10    ETA(J,K)=0.0                                                          WAVS0680
      DC 15 J=1,2                                                           WAVS0690
      FXW(J) = 0.0                                                          WAVS0700
      FYW(J) = 0.0                                                          WAVS0710
      FZW(J) = 0.C                                                          WAVS0720
      FKW(J) = 0.0                                                          WAVS0730
      FMW(J) = 0.C                                                          WAVS0740
      FNW(J) = 0.0                                                          WAVS0750
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```
   15 CONTINUE                                                   WAVS0760
      XSS = -XS                                                  WAVS0770
      IF (IMT.EQ.2)  XSS = XMI(IX)                               WAVS0780
      IP = 1   +(THEBAR*RAD-STH)/DTH                             WAVS0790
      IP=MAX0(MIN0(IP,NTH),1)                                    WAVS0800
      IP1=MIN0(IP+1,NTH)                                         WAVS0810
      DTHETA=(IP-1)*DTH+STH                                      WAVS0820
      DIP= (THETA*RAD-DTHETA)/DTH                                WAVS0830
C     TIME RISE FACTOR FOR WAVE AMPLITUDE                        WAVS0840
      AMPFAC=1.-EXP(-TIME/AMPTC)                                 WAVS0850
      DO 100 I=1,NWAVE                                           WAVS0860
      OM1=OMEGA(I)                                               WAVS0870
      OM2=OM1*OM1                                                WAVS0880
      XWK=OM2/G                                                  WAVS0890
      AA=AW(I)*AMPFAC                                            WAVS0900
      FT= OM1*TIME+XWK*FO                                        WAVS0910
      AL=XWK*COGAM                                               WAVS0920
      IAA= 1+(ABS(AL)-SAL)/DAL                                   WAVS0930
      IAA=MAX0(MIN0(IAA,NAL),1)                                  WAVS0940
      IAA1=MIN0(IAA+1,NAL)                                       WAVS0950
      DAA= (IAA-1)*DAL+SAL                                       WAVS0960
      DIA= (ABS(AL)-DAA)/DAL                                     WAVS0970
      SALP=SIGN(1.,AL)                                           WAVS0980
C                                                                WAVS0990
C     WAVE FORCES AND MOMENTS ON THE SIDEWALLS                   WAVS1000
C                                                                WAVS1010
      DO 40 J=1,2                                                WAVS1020
      YLSW=(2*J-3)*YSW                                           WAVS1030
      WE=FT+XWK*SIGAM*YLSW                                       WAVS1040
      ST=SIN(WE)                                                 WAVS1050
      CT=COS(WE)                                                 WAVS1060
      DS= ZBAR+ZS+YLSW*PHIBAR                                    WAVS1070
      DSR=DS-(XREF-XS)*THEBAR                                    WAVS1080
      ID=1.+(DSR*12.-SDS)/DDS                                    WAVS1090
      ID=MAX0(MIN0(ID,NDS),1)                                    WAVS1100
      DDSR =(ID-1)*DDS +SDS                                      WAVS1110
      DID= (DSR*12.-DDSR)/DDS                                    WAVS1120
      ID1=MIN0(ID+1,NDS)                                         WAVS1130
      DSS=DS-XSS*THEBAR                                          WAVS1140
      ZOR1=(SIGN(1.,DSS)+1.)/2.                                  WAVS1150
      DSS=DSS*ZOR1                                               WAVS1160
      IDSS=1.5+(DSS-SBB)/DBB                                     WAVS1170
      IDSS=MIN0(NBB,IDSS)                                        WAVS1180
      BS=BB(IDSS)                                                WAVS1190
      CK = COS(XWK*COGAM*XSS)                                    WAVS1200
      A33S=(RHO*PI*BS**2)/8.                                     WAVS1210
      SK = SIN(XWK*COGAM*XSS)                                    WAVS1220
      A22S=(RHO*.4*PI*DSS**2)/2.                                 WAVS1230
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      A42S=0.0                                                          WAVS1240
C                                                                       WAVS1250
C     INTERPOLATION OF WAVE TABLES                                      WAVS1260
C                                                                       WAVS1270
      K=1                                                               WAVS1280
      L=IAA                                                             WAVS1290
 41   CONTINUE                                                          WAVS1300
      BCC=AC0( L,ID,IP)                                                 WAVS1310
      BCOC=AC00( L,ID,IP)                                               WAVS1320
      BC1=AC1( L,ID,IP)                                                 WAVS1330
      BC2=AC2( L,ID,IP)                                                 WAVS1340
      BC3=AC3( L,ID,IP)                                                 WAVS1350
      BC4=AC4( L,ID,IP)                                                 WAVS1360
      BC5=AC5( L,ID,IP)                                                 WAVS1370
      BC6=AC6( L,ID,IP)                                                 WAVS1380
      BC7=AC7( L,ID,IP)                                                 WAVS1390
      BC8=AC8( L,ID,IP)                                                 WAVS1400
      BSC=AS0( L,ID,IP)                                                 WAVS1410
      BSCC=AS00( L,ID,IP)                                               WAVS1420
      BS1=AS1( L,ID,IP)                                                 WAVS1430
      BS2=AS2( L,ID,IP)                                                 WAVS1440
      BS3=AS3( L,ID,IP)                                                 WAVS1450
      BS4=AS4( L,ID,IP)                                                 WAVS1460
      BS5=AS5( L,ID,IP)                                                 WAVS1470
      BS6=AS6( L,ID,IP)                                                 WAVS1480
      BS7=AS7( L,ID,IP)                                                 WAVS1490
      BS8=AS8( L,ID,IP)                                                 WAVS1500
      WC0 (K)=BC0 +DID*(AC0 (L,ID1,IP)-BC0 ) +DIP*(AC0 (L,ID,IP1)-BC0   WAVS1510
     1    +DID*(AC0 (L,ID1,IP1)-AC0 (L,ID,IP1)-AC0 (L,ID1,IP)+BC0 ))    WAVS1520
      WC00(K)=BC00+DID*(AC00(L,ID1,IP)-BC00) +DIP*(AC00(L,ID,IP1)-BC00  WAVS1530
     1    +DID*(AC00(L,ID1,IP1)-AC00(L,ID,IP1)-AC00(L,ID1,IP)+BC00))    WAVS1540
      WC1 (K)=BC1 +DID*(AC1 (L,ID1,IP)-BC1 ) +DIP*(AC1 (L,ID,IP1)-BC1   WAVS1550
     1    +DID*(AC1 (L,ID1,IP1)-AC1 (L,ID,IP1)-AC1 (L,ID1,IP)+BC1 ))    WAVS1560
      WC2 (K)=BC2 +DID*(AC2 (L,ID1,IP)-BC2 ) +DIP*(AC2 (L,ID,IP1)-BC2   WAVS1570
     1    +DID*(AC2 (L,ID1,IP1)-AC2 (L,ID,IP1)-AC2 (L,ID1,IP)+BC2 ))    WAVS1580
      WC3 (K)=BC3 +DID*(AC3 (L,ID1,IP)-BC3 ) +DIP*(AC3 (L,ID,IP1)-BC3   WAVS1590
     1    +DID*(AC3 (L,ID1,IP1)-AC3 (L,ID,IP1)-AC3 (L,ID1,IP)+BC3 ))    WAVS1600
      WC4 (K)=BC4 +DID*(AC4 (L,ID1,IP)-BC4 ) +DIP*(AC4 (L,ID,IP1)-BC4   WAVS1610
     1    +DID*(AC4 (L,ID1,IP1)-AC4 (L,ID,IP1)-AC4 (L,ID1,IP)+BC4 ))    WAVS1620
      WC5 (K)=BC5 +DID*(AC5 (L,ID1,IP)-BC5 ) +DIP*(AC5 (L,ID,IP1)-BC5   WAVS1630
     1    +DID*(AC5 (L,ID1,IP1)-AC5 (L,ID,IP1)-AC5 (L,ID1,IP)+BC5 ))    WAVS1640
      WC6 (K)=BC6 +DID*(AC6 (L,ID1,IP)-BC6 ) +DIP*(AC6 (L,ID,IP1)-BC6   WAVS1650
     1    +DID*(AC6 (L,ID1,IP1)-AC6 (L,ID,IP1)-AC6 (L,ID1,IP)+BC6 ))    WAVS1660
      WC7 (K)=BC7 +DID*(AC7 (L,ID1,IP)-BC7 ) +DIP*(AC7 (L,ID,IP1)-BC7   WAVS1670
     1    +DID*(AC7 (L,ID1,IP1)-AC7 (L,ID,IP1)-AC7 (L,ID1,IP)+BC7 ))    WAVS1680
      WC8 (K)=BC8 +DID*(AC8 (L,ID1,IP)-BC8 ) +DIP*(AC8 (L,ID,IP1)-BC8   WAVS1690
     1    +DID*(AC8 (L,ID1,IP1)-AC8 (L,ID,IP1)-AC8 (L,ID1,IP)+BC8 ))    WAVS1700
      WS0 (K)=BS0 +DID*(AS0 (L,ID1,IP)-BS0 ) +DIP*(AS0 (L,ID,IP1)-BS0   WAVS1710
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     1    +DID*(ASO (L,ID1,IP1)-ASO (L,ID,IP1)-ASO (L,ID1,IP)+BSO ))      WAVS1720
      WSOO(K)=BSOO+DID*(ASOO(L,ID1,IP)-BSOO) +DIP*(ASOO(L,ID,IP1)-BSOO     WAVS1730
     1    +DID*(ASOO(L,ID1,IP1)-ASOO(L,ID,IP1)-ASOO(L,ID1,IP)+BSOO))       WAVS1740
      WS1 (K)=BS1 +DID*(AS1 (L,ID1,IP)-BS1 ) +DIP*(AS1 (L,ID,IP1)-BS1      WAVS1750
     1    +DID*(AS1 (L,ID1,IP1)-AS1 (L,ID,IP1)-AS1 (L,ID1,IP)+BS1 ))       WAVS1760
      WS2 (K)=BS2 +DID*(AS2 (L,ID1,IP)-BS2 ) +DIP*(AS2 (L,ID,IP1)-BS2      WAVS1770
     1    +DID*(AS2 (L,ID1,IP1)-AS2 (L,ID,IP1)-AS2 (L,ID1,IP)+BS2 ))       WAVS1780
      WS3 (K)=BS3 +DID*(AS3 (L,ID1,IP)-BS3 ) +DIP*(AS3 (L,ID,IP1)-BS3      WAVS1790
     1    +DID*(AS3 (L,ID1,IP1)-AS3 (L,ID,IP1)-AS3 (L,ID1,IP)+BS3 ))       WAVS1800
      WS4 (K)=BS4 +DID*(AS4 (L,ID1,IP)-BS4 ) +DIP*(AS4 (L,ID,IP1)-BS4      WAVS1810
     1    +DID*(AS4 (L,ID1,IP1)-AS4 (L,ID,IP1)-AS4 (L,ID1,IP)+BS4 ))       WAVS1820
      WS5 (K)=BS5 +DID*(AS5 (L,ID1,IP)-BS5 ) +DIP*(AS5 (L,ID,IP1)-BS5      WAVS1830
     1    +DID*(AS5 (L,ID1,IP1)-AS5 (L,ID,IP1)-AS5 (L,ID1,IP)+BS5 ))       WAVS1840
      WS6 (K)=BS6 +DID*(AS6 (L,ID1,IP)-BS6 ) +DIP*(AS6 (L,ID,IP1)-BS6      WAVS1850
     1    +DID*(AS6 (L,ID1,IP1)-AS6 (L,ID,IP1)-AS6 (L,ID1,IP)+BS6 ))       WAVS1860
      WS7 (K)=BS7 +DID*(AS7 (L,ID1,IP)-BS7 ) +DIP*(AS7 (L,ID,IP1)-BS7      WAVS1870
     1    +DID*(AS7 (L,ID1,IP1)-AS7 (L,ID,IP1)-AS7 (L,ID1,IP)+BS7 ))       WAVS1880
      WS8 (K)=BS8 +DID*(AS8 (L,ID1,IP)-BS8 ) +DIP*(AS8 (L,ID,IP1)-BS8      WAVS1890
     1    +DID*(AS8 (L,ID1,IP1)-AS8 (L,ID,IP1)-AS8 (L,ID1,IP)+BS8 ))       WAVS1900
      IF(K .EQ. 2) GOTO 42                                                 WAVS1910
      K=2                                                                  WAVS1920
      L =IAA1                                                              WAVS1930
      GOTO 41                                                              WAVS1940
   42 BCC = WCO (1)+DIA*(WCO (2)-WCO (1))                                  WAVS1950
      BCCO= WCOO(1)+DIA*(WCOO(2)-WCOO(1))                                  WAVS1960
      BC1 = WC1 (1)+DIA*(WC1 (2)-WC1 (1))                                  WAVS1970
      BC2 = WC2 (1)+DIA*(WC2 (2)-WC2 (1))                                  WAVS1980
      BC3 = WC3 (1)+DIA*(WC3 (2)-WC3 (1))                                  WAVS1990
      BC4 = WC4 (1)+DIA*(WC4 (2)-WC4 (1))                                  WAVS2000
      BC5 = WC5 (1)+DIA*(WC5 (2)-WC5 (1))                                  WAVS2010
      BC6 = WC6 (1)+DIA*(WC6 (2)-WC6 (1))                                  WAVS2020
      BC7 = WC7 (1)+DIA*(WC7 (2)-WC7 (1))                                  WAVS2030
      BC8 = WC8 (1)+DIA*(WC8 (2)-WC8 (1))                                  WAVS2040
      BSO =(WSO (1)+DIA*(WSO (2)-WSO (1)))*SALP                            WAVS2050
      BSOO=(WSOO(1)+DIA*(WSOO(2)-WSOO(1)))*SALP                            WAVS2060
      BS1 =(WS1 (1)+DIA*(WS1 (2)-WS1 (1)))*SALP                            WAVS2070
      BS2 =(WS2 (1)+DIA*(WS2 (2)-WS2 (1)))*SALP                            WAVS2080
      BS3 =(WS3 (1)+DIA*(WS3 (2)-WS3 (1)))*SALP                            WAVS2090
      BS4 =(WS4 (1)+DIA*(WS4 (2)-WS4 (1)))*SALP                            WAVS2100
      BS5 =(WS5 (1)+DIA*(WS5 (2)-WS5 (1)))*SALP                            WAVS2110
      BS6 =(WS6 (1)+DIA*(WS6 (2)-WS6 (1)))*SALP                            WAVS2120
      BS7 =(WS7 (1)+DIA*(WS7 (2)-WS7 (1)))*SALP                            WAVS2130
      BS8 =(WS8 (1)+DIA*(WS8 (2)-WS8 (1)))*SALP                            WAVS2140
C                                                                          WAVS2150
C     SHIFT MOMENT CENTER FROM XREF TO C.G.                                WAVS2160
C                                                                          WAVS2170
      BCCO = BCOO-(XS-XREF)*BCO                                            WAVS2180
      BC3  = BC3 -(XS-XREF)*BC1                                            WAVS2190
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```
      BC4  = BC4 -(XS-XREF)*BC2
      BC6  = BC6 -(XS-XREF)*BC5
      BSCO = BS00-(XS-XREF)*BS0
      BS3  = BS3 -(XS-XREF)*BS1
      BS4  = BS4 -(XS-XREF)*BS2
      BS6  = BS6 -(XS-XREF)*BS5
C
C     CALCULATE WAVE FORCES AND MOMENTS
C
      FZC= BS1-XWK*G*(BS2+BS0)-U*OM1*(-A33S*CK-AL*BS2)
      FZS= BC1-XWK*G*(BC2+BC0)+U*OM1*(-A33S*SK+AL*BC2)
      FMC= BS3-XWK*G*(BS4+BS00)-U*OM1*(-A33S*XSS*CK-BC2-AL*BS4)
      FMS= BC3-XWK*G*(BC4+BC00)+U*OM1*(-A33S*XSS*SK-BS2+AL*BC4)
      FYC= XWK*G*(BC5+BC0)-U*OM1*(-A22S*SK+AL*BC5)
      FYS= -XWK*G*(BS5+BS0)-U*OM1*(-A22S*CK-AL*BS5)
      FNC= XWK*G*(BC6+BC00)-U*OM1*(-A22S*XSS*SK-BS5+AL*BC6)
      FNS= -XWK*G*(BS6+BS00)-U*OM1*(-A22S*XSS*CK-BC5-AL*BS6)
      FKC=XWK*G*(BC7-BC8)+U*OM1*(-A42S*SK+AL*BC8)
      FKS= -XWK*G*(BS7-BS8)+U*OM1*(-A42S*CK-AL*BS8)
      FZW(J)=FZW(J)-AA*(FZC*CT+FZS*ST)
      FMW(J)=FMW(J)+AA*(FMC*CT+FMS*ST)
      FYW(J)=FYW(J)-AA*(FYC*CT+FYS*ST)*SIGAM
      FNW(J)=FNW(J)-AA*(FNC*CT+FNS*ST)*SIGAM
      FKW(J)=FKW(J)-AA*(FKC*CT+FKS*ST)*SIGAM
      FXW(J)= FXW(J)-2.*AA*RHO*G*BS*DSS*SK*CT
   40 CONTINUE
      IF (IMT.EQ.2)  GO TO 100
C
C     WAVE ELEVATION AROUND THE SIDEWALLS AND SEALS
C
      DO 20 J=1,4
      N=NSTA(J)
      DO 20 K=1,N
      ETA(J,K)=ETA(J,K)+SIN(XWK*(- XX(J,K)*COGAM-YY(J,K)*SIGAM)+FT)*AA
20    CONTINUE
      ETACG=ETACG+AA*SIN(FT)
      N=NSTA(3)
      DO 25 J=1,N
      ARG=AA*COS(XWK*(-XX(3,J)*COGAM)+FT)
      DETABX(J)=DETABX(J)-XWK*COGAM*ARG
   25 CONTINUE
      N=NSTA(4)
      DO 30 J=1,N
      ARG=AA*COS(XWK*(-XX(4,J)*COGAM)+FT)
      DETADX(J)=DETADX(J)-XWK*COGAM*ARG
   30 CONTINUE
C
C     WAVE PUMPING
```

```
C                                                                       WAVS2680
      X1=XWK*XLBW*COGAM/2.                                              WAVS2690
      X2=XWK*XBBW*SIGAM/2.                                              WAVS2700
      FTT=FT-XWK*XCPC*COGAM                                             WAVS2710
      DVCLW=DVOLW+AA*ABW*T2(X1)*T2(X2)*SIN(FTT)                         WAVS2720
100   CCNTINUE                                                          WAVS2730
      IF (IMT.EQ.2)  RETURN                                             WAVS2740
C                                                                       WAVS2750
C     TCTAL WAVE FORCES AND MOMENTS                                     WAVS2760
C                                                                       WAVS2770
      FXWAV=FXW(1)+FXW(2)                                               WAVS2780
      FYWAV=FYW(1)+FYW(2)                                               WAVS2790
      FZWAV=FZW(1)+FZW(2)                                               WAVS2800
      FKWAV=FKW(1)+FKW(2)+(FZW(2)-FZW(1))*YSW      +FYWAV*ZBAR          WAVS2810
      FMWAV=FMW(1)+FMW(2)-FXWAV*ZBAR                                    WAVS2820
      FNWAV=FNW(1)+FNW(2)+(FXW(1)-FXW(2))*YSW                           WAVS2830
      IF (IWAVES.NE.ON) RETURN                                          WAVS2840
                WRITE(6,200)  ((ETA(I,J),J=1,11),I=1,4),ETACG,CVOLW     WAVS2850
     1,FXWAV,FYWAV,FZWAV,FKWAV,FMWAV,FNWAV                              WAVS2860
C                                                                       WAVS2870
  200 FCRMAT(/10X,5HWAVES /63H WAVE ELEVATIONS AT CRAFT STATIONS RELATIVWAVS2880
     1E TO CALM WATER (FT.) /14H PORT SICEWALL /11F10.5/14H STBC SICEWALWAVS2890
     2L /11F10.5/9H BOW SEAL /11F10.5/11H STERN SEAL /11F10.5/25H WAVE EWAVS2900
     3LEVATION AT C.G. = F10.5,10X,43HPLENUM VOLUME LOST DUE TO WAVES (CWAVS2910
     4U. FT.) = F15.5/10X,23HWAVES FX,FY,FZ,FK,FM,FN /6E15.4)           WAVS2920
C                                                                       WAVS2930
      RETURN                                                            WAVS2940
      END                                                               WAVS2950
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